

JOURNAL OF THE INSTITUTION OF CIVIL ENGINEERS.

No. 8. 1941-42.

OCTOBER 1942.

ORDINARY MEETING.

12 May, 1942.

PROFESSOR CHARLES EDWARD INGLIS, O.B.E., M.A., LL.D.,
F.R.S., President, in the Chair.

The Council reported that they had recently transferred to the class of

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Students.

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 CHARLES MCGREGOR WILSON.

The Scrutineers reported that the following had been duly elected

Associate Members.

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 WILLIAM ALEXANDER SMITH, B.Sc. (*Andrews*), Stud. Inst. C.E.
 RICHARD D'AVRAY WILLIAMS, B.Sc. (*Eng.*) (*Lond.*), Stud. Inst. C.E.

The following Paper was submitted for discussion, and, on the motion of the President, the thanks of The Institution were accorded to the Author.

Paper No. 5323.

"Treatment of Water for Domestic and Industrial Requirements:
Some Problems and Methods." †

BY ALBERT PARKER, D.Sc.

TABLE OF CONTENTS.

	PAGE
Quantities of water available and required	365
Need for comprehensive survey of quantity and quality	366
Prevention of pollution	369
Objects of treatment	370
Removal of suspended and colloidal matter	371
Algal growths	371
Water weeds	373
Filtration	374
Disinfection or sterilization	375
Iron and manganese	377
Softening	378
Corrosive waters	383
Iodine	384
Fluorine	385

QUANTITIES OF WATER AVAILABLE AND REQUIRED.

THE average annual rainfall over Great Britain is about 39 inches, or 560 million gallons per square mile. As the area is approximately 88,750 square miles, the average annual precipitation over the whole of Great Britain is about 50 billion gallons, or an average of 137,000 million gallons per day, which is equivalent to 3,000 gallons per person per day for a population of 45 millions. A large part of this rainfall is lost by evaporation and probably only about 60 per cent., or 1,800 gallons per person per day, flows into rivers and streams and underground reservoirs.

In comparison with this quantity of 1,800 gallons, the average consumption of water for domestic purposes is only 20-25 gallons per person per day. In addition to the water required for domestic purposes, large quantities are used by industry. Many factories each use several millions of gallons per day in manufacturing processes, in raising steam, and in coolers and condensers. Railway undertakings use very large quantities. Electricity generating stations with steam-driven plant circulate through the condensers about 60 gallons of cooling water for each unit generated,

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or approximately 100,000 gallons per ton of coal consumed. This means that authorized electricity supply undertakings in Great Britain, apart from generating-stations owned by railway, tramway, and certain non-statutory bodies, circulate through the condensers a quantity of water of the order of 3,000 million gallons per day. The water circulated through coolers and condensers is not always fresh water; sea-water and brackish water from estuaries are often used. In many instances the cooling water is cooled and re-used. There is no doubt, however, that the quantity of water withdrawn by industrial undertakings direct from surface and underground sources is greater than the quantity distributed by water supply authorities, though how much greater is not known, owing to lack of data.

It seems probable that the total quantity of fresh water used for domestic and industrial purposes in Great Britain does not exceed 100 million gallons per person per day, or 6 per cent. of the net quantity available from rain, after allowing for losses by evaporation. There should, therefore, be ample quantities of fresh water in Great Britain to meet any probable future demands, even assuming a great expansion in manufacturing processes requiring large volumes of water.

NEED FOR COMPREHENSIVE SURVEY OF QUANTITY AND QUALITY.

Although the total quantity of water available from rain in Great Britain is probably about twenty times as great as the quantity required for domestic and industrial purposes, water-supply undertakings and industries have frequently experienced difficulties in obtaining suitable supplies within reasonable distance of the areas of supply and of the sites occupied by the factories. There are several reasons for these difficulties. Rain water, as it flows over and through the ground to enter rivers, streams, springs, and underground reservoirs, dissolves some of the substances with which it comes into contact. In some instances the nature and concentration of the dissolved substances are such that the water most easily accessible to towns and factories are quite unfit, except after costly treatment, for the purposes for which they are required; moreover, in numerous instances the local water resources are badly polluted by domestic and industrial wastes. One of the main reasons for the difficulties which have been encountered is that in the development of towns and urban areas and the establishment of industries, insufficient attention has been given to the quantity and quality of the water required and to the problems which arise in the disposal of sewage and trade effluent. It is by no means uncommon to find that factory sites have been acquired and the factories have been built or partly built before the questions of water-supply and the disposal of polluting waste waters have been seriously considered. In other words, there has been inadequate planning, and consequently there have been great difficulties and expense, which could

have been avoided if a more suitable site had been chosen or the factory had been differently planned.

Unfortunately, too little is known at present about the quantity and quality of most of the water resources of the country ; in consequence one essential factor in the selection of sites for factories of various kinds, and even in the satisfactory planning of towns, is often lacking.

The Geological Survey, which is part of the Department of Scientific and Industrial Research, has collected a large amount of valuable information on the underground water resources, especially during recent years, and the results have been collected in a series of water-supply memoirs and pamphlets. Much more information, however, is required on the quantity, and particularly on the quality, of the underground waters, on the quantities withdrawn from wells, and on the changes in levels and in quality from year to year and at different times of the year.

Information about surface waters in rivers, streams, and lakes is little or no greater than that on underground waters. Data have been collected over a number of years on the variations in flow of several rivers ; but most of the surface water resources have never been measured, and very little information has been obtained as to the quality of these waters and the changes in quality, which in some instances are considerable and occur rapidly with variations in rainfall.

In several of its published annual reports, the Water Pollution Research Board of the Department of Scientific and Industrial Research has stressed the importance of accurate information on the water resources of the country and on the variations with different conditions of weather, not only in relation to public water-supplies, land drainage, fisheries, hydro-electric schemes, electricity generating-stations, and various manufacturing processes, but also in efforts to control and prevent water pollution. The subject has been considered also on many occasions in the past by various other organizations and individuals. In 1932 a committee was appointed by the British Association for the Advancement of Science to inquire into the position of inland water survey in the British Isles and the possible organization and control of such a survey by central authority. In a report, which was published in 1933, this committee of the British Association expressed the opinions (i) that the position of inland water survey in the British Isles was far from satisfactory and that a systematic survey of the water resources of Great Britain was urgently required ; and (ii) that the survey, to be of maximum utility, should be conducted by a central organization independent of any interest in the administration, control, or use of water. A committee on Scottish Health Services appointed by the Secretary of State for Scotland also recommended, in a report issued in 1934, that a technical survey of the water resources and supplies of Scotland should be undertaken at once. Following the recommendations of these two committees, an Inland Water Survey Committee was set up

early in 1935 by the Ministry of Health and the Secretary of State for Scotland to advise on the inland water survey for Great Britain, on the progress of the measures undertaken, and on further measures required, and, in particular, to make an annual report on the subject. Under the guidance of this committee, which has issued three annual reports and a useful memorandum on methods of surveying river systems and of recording results, a systematic survey was begun, and Surface Water Year Books of Great Britain for 1935-36 and 1936-37 have been published, in which statistical data on the flow of a number of rivers were given; but no reliable data were available for most of the rivers. The object of the Survey is to collect and correlate available records of surface and underground waters in Great Britain, to encourage the keeping of records, and to make the results available for general use. The work of gauging and recording has been carried out not directly by the committee, but by various organizations and individuals; it is the main task of the Survey to examine and co-ordinate the data supplied by the various agencies and to arrange them in a form suitable for publication. In the work carried out before the war, the Survey had the close co-operation of the Geological Survey and the British Rainfall Organization of the Meteorological Office.

Records of rainfall have been collected systematically in Great Britain since 1860, when the British Rainfall Organization was founded by G. J. Symons as a private enterprise. In 1919 the accumulated records were acquired by the Government and the responsibility for continuing the work was entrusted to the Meteorological Office of the Air Ministry. The measurements of rainfall have been extended gradually and records are now obtained from gauges in all parts of the British Isles. The comprehensive records are collected and collated by the organization and are published in the annual volume known as "British Rainfall." The organization is not officially concerned with run-off; it is prepared to accept the responsibility for estimating the quantities of rainfall that may be expected over different areas, but is not prepared to estimate how much of the rainfall may be available for domestic or other purposes. In the absence of direct measurements of water carried by rivers and streams under various conditions of weather, it has frequently been necessary for water engineers and others to make approximate estimates of river flow from the data for rainfall, allowance being made for probable losses by evaporation and percolation.

The position, therefore, is that fairly comprehensive records of rainfall are available and are being collected, but that the data on the quantities of surface and underground water are far from adequate, and very few records on the quality of the waters are available. It is to be hoped that when peaceful times return the work on underground waters by the Geological Survey and the records begun by the Inland Water Survey Committee can be widely and rapidly extended and that arrangements

will be made systematically to collect records on the quality of the surface and underground supplies. Unless such surveys are undertaken rapidly and systematically, satisfactory planning of towns, industries, and urban and rural areas will not be possible. In consequence water will in many instances be drawn from sources inadequate in quantity or unsuitable in quality, whilst in some instances costly methods of treatment will have to be adopted, which might otherwise have been avoided; unnecessary pollution of many rivers and streams and underground waters will also continue. Ample water-supplies of suitable quality and satisfactory schemes of sanitation and of disposal of trade effluents are of primary importance to the individual, to the community generally, and to many industries. This fact, however, has never been properly recognized in general schemes of planning in Great Britain, though in certain other countries fairly comprehensive schemes of survey of water resources have been in operation for many years.

PREVENTION OF POLLUTION.

A good source of supply is one which provides an ample quantity of water at all times, including relatively dry years, to meet any probable maximum demand. The water should be free from extraneous pollution, as judged by stringent chemical and bacteriological tests, and should not contain undesirable substances such as compounds of iron, manganese, and lead; it should also be clear and bright, fairly soft, and of reasonably uniform composition, and should have no appreciable action on the materials ordinarily used for mains, service pipes, and fittings. Such waters require little or no preliminary treatment before distribution. The relatively few available sources of this kind are mainly deep wells, with a few springs and shallow wells, and the surrounding areas have to be very carefully protected to ensure that there is no risk of contamination. In most instances the water requires treatment by one or more processes to render it suitable for public supply. River waters in Great Britain almost invariably require drastic treatment, as most of the rivers receive polluting discharges of one kind or another, often in considerable quantities. Unfortunately, the relatively few available sources of unpolluted water are being gradually depleted and already many of the largest public supplies are drawn from rivers which are to some extent polluted. With extensions of modern methods of sanitation and the changes and developments in industry, it is certain that in the future a greater demand will be made on the water resources of the country; and many rivers now receiving appreciable quantities of polluting discharges will have to be used as sources of supply, after treatment, for domestic and industrial purposes. The first important line of action, therefore, is to find practicable methods whereby the pollution of the water resources can be considerably reduced, not entirely prevented.

Great and rapid improvement in the condition of many rivers, especially in highly industrialized areas, however, cannot be easily achieved, as it involves numerous difficult problems of treatment and disposal of trade effluents of many kinds. The subject has been considered by several Royal Commissions, particularly the two Commissions on River Pollution appointed in 1865 and 1868 and the Commission on Sewage Disposal which received a large quantity of evidence and conducted many experimental investigations during seventeen years from 1898 to 1915. The Royal Commission on Sewage Disposal, whose comprehensive inquiry included the consideration of methods of treatment and disposal not only of sewage but also of trade effluents, expressed the opinion that satisfactory means of disposal of many trade effluents were unknown, and that the problems involved could not be solved without further knowledge. In consequence of this opinion and of the views expressed by several Government Departments, various organizations, and individuals, the Water Pollution Research Board was set up in 1927 by the Department of Scientific and Industrial Research.

Since its appointment the Board has found satisfactory methods of dealing with the polluting waste waters from beet sugar factories and from dairies and milk products factories, and has developed an improved method of treatment of sewage by means of percolating filters. The Board is concerned not only with problems of the disposal of sewage and trade effluent, but also with the problem of treatment of water to render it satisfactory for public supply. Investigations have been carried out on the base-exchange process of water softening, the removal of dissolved salts from water, the causes and prevention of the corrosive and leaching dissolving action of certain waters on mains, service pipes, and fittings, and the fundamental bacteriology of fresh waters. In addition, a comprehensive chemical, biological, and hydrographical survey of the river Tees has been carried out, and an investigation has been completed on the effect of discharges of crude sewage upon the deposition of solid matter in the estuary of the river Mersey from the point of view of navigation.

OBJECTS OF TREATMENT.

After ensuring that the source of water for public supply or for certain industrial processes is kept as free from pollution as possible, the next step is to decide upon the treatment necessary to render the water suitable for the purposes for which it is required. Various stages of treatment may be desirable with one or more of the following objects: (i) removal of suspended and colloiddally dispersed substances; (ii) destruction or prevention of algal and other growths in the water in reservoirs, swimming-baths, condensers, and coolers; (iii) removal of iron and manganese, and sometimes fluorine; (iv) reduction of hardness caused by salts of calcium and magnesium, and sometimes the removal of other

dissolved salts ; (v) improvement of colour, odour, and taste ; (vi) destruction of harmful bacteria and other organisms ; and (vii) treatment to prevent or reduce the plumbo-solvent and corrosive action of the water.

REMOVAL OF SUSPENDED AND COLLOIDAL MATTER.

Removal of the coarser suspended matter can be achieved by simple sedimentation in reservoirs or in tanks specially designed for the purpose. Simple sedimentation, however, does not remove very fine suspended matter and colloidal substances of the kind frequently present in water from peaty, moorland areas. The removal of the fine suspended and colloidal matter is usually effected by the addition of a chemical coagulating agent, followed by mixing, sometimes sedimentation, and filtration of the water through fine sand or similar material. Aluminium sulphate, in quantity equivalent to from 0.5 part to 4 parts, and sometimes as much as 7 parts per 100,000, is the coagulant usually employed, although during recent years other substances, such as ferrous sulphate (copperas), chlorinated ferrous sulphate, sodium aluminate, and mixtures of aluminium sulphate and sodium aluminate have been used with success in certain instances. The coagulant not only assists in coagulating or flocculating the suspended and colloidal matter, but also causes the deposition of a thin gelatinous film on the grains of the filter, thus aiding the filter in removing the last traces of suspended and colloidal matter and in removing bacteria. The efficiency of coagulation varies with the quantity of coagulant added, the method of mixing, the time of contact or conditioning of the floc, the alkalinity or acidity (pH value), and the nature and concentration of the suspended matter and salts in solution. So many factors have to be considered that, although certain broad principles have been established, the best conditions and the best coagulant or mixture of coagulants for any particular water can be determined only by experiments with that water. The coagulant itself may alter the pH value of the water, and with some waters of an acid character the pH value has to be raised by the addition of lime or soda.

It was shown by the late Sir Alexander Houston that storage of water in reservoirs for long periods—20 or 30 days or more—not only removes suspended solid matter by sedimentation, but may also bring about the destruction of such harmful pathogenic organisms as *B. typhosus*, *B. paratyphosus B.*, and cholera vibrio.

ALGAL GROWTHS.

Prolonged storage of water exposed to light, however, may give rise to abundant growths of algae, particularly if the water is slightly contaminated with organic matter which can serve as a nutrient or fertilizer for the algae. Algal growths are usually more prolific from the beginning

of April to early June, and from the end of August to the middle of October than at other times of the year; they often appear fairly suddenly and develop rapidly. Later they decay and leave organic matter which encourages the growth of another crop at the next suitable season. These growths may cause considerable difficulties by blocking sand filters, which in consequence have to be cleaned more frequently, and the products of their metabolism or decomposition may impart to the water an unpleasant taste and odour. Troublesome growths of algae develop not only in many lakes, reservoirs, and ponds, but also sometimes in artificial swimming pools, even when the water is treated periodically with small doses of chlorine or of the chlorinating agents bleaching powder and sodium hypochlorite.

In attempts to overcome difficulties caused by growths of algae, prevention is far better than cure. In the first place every effort should be made to prevent contamination of the water by nutrient substances, including organic matter, nitrates, and phosphates. Even when everything possible has been done in this direction, the composition of the water and the conditions, including the intensity of light, may be such that algal growths will occur unless some reagent is added to the water to prevent them. Methods for the prevention and destruction of algal growths include the addition to the water of copper sulphate (0.1-1.0 part per million), potassium permanganate (0.2-0.5 part per million), or chlorine (0.5-1.0 part per million) in the form of gas, aqueous solution, hypochlorite, or chloramine. The most suitable algicide and the dose and method of application are dependent upon the species of algae, the composition of the water, and other conditions. Although experience has shown that the quantity of algicide to be added on each application is usually in the range indicated by the figures given in brackets, circumstances occur in which larger quantities are required. Of the algicides mentioned, copper sulphate is generally the most successful, and is less costly than potassium permanganate. An average dose of copper sulphate is about 0.6 part by weight of the crystalline salt per million parts of water. The first dose should be applied before growth of algae ordinarily begins, say at the end of April, and it may be necessary to add a similar dose at intervals of a few days or a week over a period of about 2 months. Further similar doses may be required from the end of August until early in October. The dose required and the frequency of application, however, can be selected only as a result of trials under each particular set of conditions. Copper sulphate can be sprayed as a solution in water or it can be applied by dragging a sack of copper sulphate behind a boat. The copper sulphate in solution reacts slowly with the water to form insoluble copper hydroxide, which settles out as a precipitate. As a result, the treated water does not contain so much soluble copper salt as the quantity added. With hard alkaline waters more copper sulphate is needed than with softer waters, as more of the copper salt is precipitated as hydroxide.

within the first few hours after the addition of the salt. In treating swimming-baths to prevent algal growths, it is sometimes advantageous to scrub the walls and floor of the bath, after it has been emptied, with a 5-per cent. solution of crystalline copper sulphate and then to wash the walls and floor with a small quantity of water and drain the bath before re-filling it with water; it may also be necessary on occasions to add copper sulphate to the water in an amount equivalent to about 0.6 part per million. Experience has indicated that continuous small doses of chlorine or chlorinating agents are not so effective as occasional large doses in preventing algal growths. It is doubtful whether chloramine is satisfactory for preventing growths of algae, and whether so-called cuprichloramine is any more effective than the corresponding dose of copper sulphate without chlorine and ammonia.

WATER WEEDS.

Difficulties are sometimes caused by excessive growths of true water weeds and of emergent weeds such as rushes and reeds in rivers, lakes, and natural reservoirs. Water weeds are mainly large plants with stems and leaves similar to those of land plants, but which grow underneath or floating on the water. Emergent weeds grow upright on the margin of lakes and ponds or in shallow water. Both water weeds and emergent weeds are much larger than the minute green or brown plants known as algae. The food of water weeds and emergent weeds exists partly in the deposit of mud or other material on the bed of the lake or pond. If the bed is clean, firm, and sandy, it is comparatively poor in nutrient substances and heavy growths of weeds are improbable. If the bed consists of soft black mud, the quantity of nutrient substances is probably considerable and heavy growths of weeds may occur. When the weeds die and decay they leave material suitable as fertilizer for another crop at the appropriate season. Every effort should be made, therefore, to maintain the bed in as clean a condition as possible and to prevent access of mud and polluting organic matter with the inflowing streams. If excessive growths of weeds do occur, they can often be largely removed by dragging, preferably in spring and autumn. The growth of water weeds can also be prevented or discouraged by adding a solution of sodium arsenite to the water to give a concentration equivalent to about 2 parts by weight of arsenious oxide or 1.5 part of arsenic in 1 million parts of water. In this concentration sodium arsenite, when applied only occasionally, is not poisonous to animals. The minimum quantity of arsenic which will cause death in man is usually considered to be 100 milligrams if taken in one dose, but the susceptibility of individuals varies considerably. Assuming that the quantity of water used by each person for drinking and cooking is 3 pints per day, a lethal concentration of arsenic in the water for one day would be about 60 parts per million. If water containing

arsenic were taken for more than one day, the lethal concentration would be smaller, as arsenic is a cumulative poison. Experiments in the Water Pollution Research Laboratory have shown that water containing sodium arsenite in a concentration equivalent to 50 parts of arsenic in 1 million is toxic to minnows in about 20 hours. Sodium arsenite is clearly a dangerous poison and should be used only under expert supervision to ensure that no part of the water contains this substance in a concentration approaching the value at which it is toxic.

Emergent weeds can be killed or discouraged by spraying them two or three times at intervals of a few days with a 2.5-per cent. solution of sodium chlorate. Even in this high concentration sodium chlorate is not poisonous to animals, but clothes saturated with the solution and then allowed to dry are highly inflammable. If waders and oilskins are worn while spraying the solution, they can easily be washed afterwards with clean water to remove any sodium chlorate.

Although solutions of copper sulphate and of potassium permanganate can be used with success in preventing or discouraging algal growths, they have little effect upon the larger water weeds and emergent weeds.

Other growths which cause difficulty are those which sometimes occur in the condensers and coolers of power-stations and other works: these growths can reduce considerably the efficiency of the cooling system. They can be prevented by adding to the water circulated during 2 or 3 hours sufficient chlorinating agent to give a concentration of free chlorine of 5-10 parts in 1 million parts of water; the dose of chlorine should be repeated at intervals of a few days. This intermittent treatment with these comparatively high concentrations of chlorine is usually more effective than the continuous application of 0.5-1.0 part of chlorine in 1 million, and it is more economical in chlorine. Copper sulphate should not be applied in attempts to prevent growths in condenser-tubes, as it may have a destructive action on the tubes.

FILTRATION.

In the past, filters to remove colloidal and other substances and bacteria have usually contained sand, and the rate of filtration has been of the order of 2 or 3 gallons of water per hour per square foot of filter-surface. In recent years considerable development has occurred in the application of mechanical or rapid sand filters with a filtration rate of the order of 100 gallons per hour per square foot. Both slow filters and rapid filters have their advantages and disadvantages, and the correct choice must depend upon particular conditions and requirements. In some instances there are advantages in employing rapid filters as a preliminary to passage of the water through slow sand filters, which can then be operated at a rate rather higher than that usual without preliminary filtration. Many investigations have been made with the object of deter-

mining the effects of changes in the nature and size-grading of the filtering medium upon the efficiency of filtration, and the effects of various factors upon the length of time during which a filter can be operated satisfactorily before it requires washing and cleaning with water, or air, or both. Further experiments will no doubt lead to improvements and to methods of overcoming some of the difficulties which have arisen in the filtration of certain waters. Filters containing graded particles of anthracite in place of sand have been used in a number of installations in the United States, and two or three anthracite filters have recently been introduced in Great Britain. They are employed mainly for removing the last traces of precipitated carbonate and hydroxide in water softened by the hot process of softening with lime and soda in preparing water for raising steam. If the hot water is filtered through sand there may be an appreciable increase in the concentration of silica in the water. In many instances the increase in the quantity of silica is a disadvantage in that it increases the risk of formation of a hard silica scale in the boiler.

DISINFECTION OR STERILIZATION.

During recent years the outstanding advances in processes of treatment of water for public supply and for use in certain industries, particularly those concerned with foods, have included the development of methods of disinfection or sterilization to render the water hygienically safe. This development has been stimulated by the fact that in many districts it has become necessary to draw supplies from rivers and streams which have received sewage and sewage effluents and other polluting discharges. Many well waters are also liable to pollution by pathogenic organisms, particularly waters from shallow wells and even from deep wells if the overlying strata contain fissures through which the water can travel direct from near the surface of the ground without filtration through a considerable depth of suitable soil or other material. Of the various methods of disinfection, the application of chlorine in the form of gas, aqueous solution, hypochlorites, or chloramine is the one usually adopted. The quantity of chlorine added is generally between 0.1 and 0.5 part per million, though larger quantities may be necessary with waters containing unusually large quantities of organic matter. Simple chlorination brings about satisfactory disinfection and destruction of harmful pathogenic organisms in a short time, but in many instances it has caused unpleasant tastes in the water even after the excess of free chlorine has been removed. With the object of overcoming difficulties of this kind, various modifications have been tried, and some of them have been applied on a large scale. These modifications include chlorination in two stages at different points in the complete system of treatment at the waterworks, the addition of larger quantities of chlorine, or so-called super-chlorination, followed later by de-chlorination with substances such as sulphur dioxide

and sodium thiosulphate, the addition of ammonia or sulphate of ammonia to form chloramines, and treatment with activated carbon to remove objectionable tastes. Chloramines are much slower in their disinfecting action than is free chlorine, but their action continues for a longer period, and thus reduces risk of contamination of the water during distribution.

Excess of free chlorine gives rise to a chlorinous taste. This can be avoided by reducing the dose of chlorine or by de-chlorination. The causes of other tastes which sometimes develop on the chlorination of water are not always easily found. For example, an appreciable unpleasant taste will develop on the chlorination of water containing so little as 1 part of phenol in 2,000 million parts of water. It has been asserted that the taste can be detected when the concentration of chlorinated phenol is even as small as 1 part in 100,000 millions. Similar tastes may also develop in chlorinated water as a result of the presence of leaves from willows and poplars, and of meadow-sweet, algae, fungi, and certain bacteria. Of the various methods of preventing or removing unpleasant tastes in water, disinfection with chloramine, in which the ammonia and chlorine may be applied separately, and treatment with activated carbon, seem to have been the most successful.

The application of chlorine as a disinfecting or sterilizing agent has now become so widespread, and so much reliance is placed upon this method, that there seems to be a tendency in some instances to relax efforts to prevent or reduce the pollution of the water-supply at the source. This tendency is to be deprecated. In ordinary times chlorination should be regarded only as an additional safeguard, and not as a reason for not exercising care in selecting the source of supply or for not doing everything possible to protect the source from pollution. The average consumer does not wish to receive water with a strong chlorinous taste, nor to consider providing equipment or chemical reagents to remove the excess chlorine. In difficult times such as the present, when water mains and sewerage systems may suddenly be damaged, it may be desirable to apply chlorine in doses larger than are ordinarily necessary, but such conditions should be considered as exceptional.

In some circumstances it may be necessary to draw emergency supplies of water from sources which are unduly contaminated. It may then be desirable to treat such waters by adding 3 or 4 parts of chlorine per million, allowing a time of contact of 1 or 2 hours, and then removing the excess chlorine by adding a solution of sodium thiosulphate. The question has accordingly arisen as to whether the presence of chlorine in an initial concentration of about 3 parts per million causes an increased action of the water on tanks, pipes, and other fittings. If the corrosive action of the water were seriously increased by the presence of so much chlorine, the water might become unduly contaminated with metals. Experiments made at the Water Pollution Research Laboratory have shown that the

presence of 3 parts of chlorine per million does not appreciably increase the action of water on lead and copper.

Other methods of disinfection in use on a large scale in some places include the addition of lime to give an excess of about 1 part in 100,000 after a reaction period of 24 hours, treatment with ozonized air, and exposure to ultra-violet light. There is also a method of disinfection by the so-called oligodynamic action of certain metals. Treatment by excess lime, with the addition of powdered active carbon before filtration to improve the taste of the water, has been successfully applied over a number of years at the Southend waterworks in Essex, and the process has also been used at several waterworks in the United States. Ozonized air has been employed for the disinfection of a number of water-supplies on the Continent, and for treating the water of several swimming-baths in Great Britain; it has been tried on a semi-commercial scale by the Metropolitan Water Board. Treatment with ozonized air has certain advantages over chlorination in that it does not produce unpleasant tastes and frequently improves the taste and appearance of the water. It is more expensive, however, than chlorination, and the water does not retain disinfecting properties for so long, as any excess ozone rapidly escapes or breaks down. Ultra-violet light has been used in some circumstances. As the penetrating power of the rays is not great, the water treated by this method must be clear and free from colour and suspended or colloidal matter, and it must pass as a thin layer when exposed to the lamps. The bactericidal action of certain metals and metallic salts has long been known, but it is only during recent years that the action has been studied with the object of its application for the treatment of water on a large scale. By the "Catadyn" process, as originally introduced, materials such as sand and porcelain are impregnated with finely-divided silver, and water is disinfected by filtration through or contact with the materials. The quantity of silver taken up by the water is generally from 0.015 to 0.06 part per million; this is sufficient to sterilize many waters after a period of contact of several hours. It seems that untreated water may be disinfected by mixing it with a proportion of water previously fully treated by the Catadyn process. Any suspended or colloidal matter adsorbed or deposited from the water on the material, however, impairs the sterilizing effect. Various modifications of the process have been introduced with the object of overcoming this difficulty; for example, by one method the silver is introduced into the water from electrodes by the action of an electric current.

IRON AND MANGANESE.

Iron and manganese in quantities of the order of from 0.1 to 0.5 part per million in water to be treated at a waterworks usually cause little difficulty, as the soluble compounds of these metals readily oxidize to produce insoluble oxides which are removed by the filters. Larger quan-

ties of these metals, especially if associated with organic compounds, may cause opalescence, colour, and unpleasant taste, and the deposition of oxides at inconvenient positions, and may render the water unsuitable for certain industrial processes, particularly in the textile industries. As little as 0.5 part per million of these metals may impart an unpleasant flavour to the water, and 1 part per million causes a distinct "inky" taste. Methods of removal of these substances include aeration, the addition of lime, sedimentation, and filtration. The manganese compound of certain base-exchange zeolites effectively removes iron and manganese, and when the zeolite is exhausted it can be regenerated by treatment with a solution of potassium permanganate. In selecting the most suitable method it is always advisable to make a number of experiments with samples of the particular water to be treated.

SOFTENING.

Several methods of softening water are now available, each with its own advantages and disadvantages according to the water to be treated and the purpose for which the water is required. At some waterworks in Great Britain the water is softened before distribution to reduce the hardness from more than 20 parts per 100,000 to approximately 10 parts. In these instances a portion of the water is softened by treatment with lime or by the base-exchange process, and the softened water is mixed with hard water for distribution. Softening at waterworks, however, is not general. As a result large numbers of consumers receiving hard water have installed household softeners utilizing the base-exchange process. If the majority of householders in a district supplied with hard water installed separate softeners, there is no doubt that the total cost of installation and operation of the numerous small softeners would be much higher than the cost of softening the supply at the works before distribution. Softening of the water at the works should, therefore, be encouraged on cost alone, apart from the fact that the extent of softening can be controlled more efficiently at the central works. Another point of importance is that the base-exchange process is the only method of softening suitable for small household softeners, though it is not the most satisfactory method for all hard waters. Some hard waters when fully treated by the base-exchange process provide a soft water with an appreciable corrosive action on galvanized tanks and pipes. In consequence the use of household softeners in some districts has led to inconvenience and expense in replacing galvanized tanks.

In its simplest form the problem of softening water consists in removing the alkaline earth metals calcium and magnesium, which are present to a greater or smaller extent as soluble bicarbonates and sulphates in most natural waters in Great Britain, and form insoluble soaps. The term "water softening" is now often used to cover not only true softening but

also the removal of all substances which may cause the formation of scale in boilers. The principal processes may be divided into three main classes : (i) those which remove the troublesome basic ions or cations, such as calcium and magnesium, by some method of precipitation ; (ii) those which replace the troublesome cation by a cation such as sodium which does not give insoluble salts or insoluble soaps ; and (iii) those which remove not only the basic ions or cations but also the acid radicals or anions, thus removing the salts to produce a water containing little or no dissolved solids. Combinations of two or more processes are employed.

Lime.—Temporary hardness caused by the presence of calcium bicarbonate in solution can be removed by adding sufficient lime to convert the bicarbonate into relatively insoluble calcium carbonate. This method has the advantage that the added lime also removes dissolved carbon dioxide which is always present when there is calcium bicarbonate in solution, as the bicarbonate does not remain dissolved unless there is free carbon dioxide in addition. If the calcium bicarbonate is removed without at the same time removing the free carbon dioxide, the treated water may not form a protective coating on metals and may, in consequence, cause serious corrosion of the metals. Lime also converts magnesium bicarbonate into relatively insoluble magnesium hydroxide. This process, however, does not remove permanent hardness caused by the presence of dissolved sulphates and chlorides of calcium and magnesium. It also suffers from some other disadvantages. For example, difficulties have arisen in ensuring rapid and complete precipitation, sedimentation, and removal of the calcium carbonate and magnesium hydroxide formed. Some water-supply undertakings have experienced trouble from the deposition or "after-precipitation" of calcium carbonate in the supply mains, and the precipitate has sometimes been carried forward into tanks and fittings on premises connected to the supply. This difficulty can be avoided by the subsequent addition of carbon dioxide to the water ; but the addition must be carefully controlled, as an excess of carbon dioxide may encourage corrosion of the mains, service pipes, and fittings. With the object of assisting precipitation in the sedimentation tanks at the works, coagulating agents such as aluminium sulphate and sodium aluminate have been used with success in many instances, though they have not always been entirely satisfactory. During recent years the addition of a small quantity of sodium hexametaphosphate, in a concentration of the order of 1 part per million, has been successfully used in certain circumstances to prevent after-precipitation. Improvement has also been effected by returning some of the previously precipitated calcium carbonate to the water undergoing treatment with lime, and by arranging the process so that the water with the added lime water flows through a layer or blanket of the precipitate ; these methods assist the formation of the precipitate and probably increase the size of the particles so that they can be removed more easily by simple sedimentation.

One problem which has not been satisfactorily solved in all instances is that of the disposal of the precipitated sludge. The quantity of sludge is considerable, amounting to about 1.5 ton of air-dried sludge, with 30-40 per cent. moisture, for a reduction of about 10 parts per 100,000 in the temporary hardness of 1 million gallons of water.

Lime-soda.—In the lime-soda process, both the temporary and the permanent hardness can be removed. Lime and sodium carbonate are added in quantities sufficient to ensure that the calcium salts are precipitated as calcium carbonate and the magnesium salts as magnesium hydroxide. As a result of the reactions which occur, the sulphates of calcium and magnesium originally in solution are replaced by the equivalent quantity of sodium sulphate. If the permanent hardness is high the treated water will contain a considerable quantity of sodium salts in solution. In other respects the advantages and disadvantages of the process are in general similar to those of the lime process. Treatment with lime and soda is used for water for many boiler installations and for water for some laundries and certain industrial processes. It is not ordinarily employed for water for public supply.

Soda and caustic soda.—In place of the lime used in the lime-soda process, caustic soda can be employed, although it is a more expensive reagent. With caustic soda the concentration of the dissolved solids in the treated water is greater than when lime is used, as one-half of the carbon dioxide of the bicarbonates and the whole of the free carbon dioxide are converted into soluble sodium carbonate. The alkalinity of the water is increased, and if the water is used for raising steam some of the sodium carbonate is converted into caustic soda in the boiler. With some waters the treatment may increase the risk of "priming"—the carrying over of solid matter with the steam—and of so-called caustic embrittlement. The quantity of sludge produced by the removal of the temporary hardness caused in the first place by calcium bicarbonate is smaller than in the lime-soda process.

Base-exchange zeolites.—The base-exchange or zeolite process of water softening, which has been utilized for many years for softening water for public supply, raising steam, and various industrial requirements, depends upon the property of base-exchange possessed by certain natural and synthetic aluminosilicates. When hard water is passed through a column of the sodium compound of the aluminosilicate, graded in particles of suitable size, the calcium and magnesium are removed from the water and are replaced by sodium. After the active sodium in the aluminosilicate has been replaced by calcium and magnesium, the material is regenerated for further use by treatment with a solution of common salt.

Three types of base-exchange zeolite are in commercial use for softening water: (i) natural glauconites; (ii) treated clays; (iii) synthetic products prepared from sodium aluminate and sodium silicate. The volume of water which can be treated by 1 cubic foot of base-exchange zeolite

reduce the hardness by 10 parts per 100,000 is very approximately 700 gallons with the glauconites, 1,100 gallons with the treated clays, and 1,800 gallons with the synthetic materials, before regeneration of the material becomes necessary. These figures form only a rough guide, as the exchange values differ appreciably with different materials of the same general type; they are also dependent upon the quantity of salt used for regeneration, the extent to which the hardness is caused by magnesium, and other factors. A deduction must also be made for the quantity of water required to wash the materials after regeneration; this is usually between 1 and 4 per cent. of the volume of water softened. The quantity of salt employed for regeneration is generally between two and four times the weight of calcium carbonate equivalent to the hardness removed.

An important point in selecting the zeolite is the relative loss of the material as the result of disintegration and the possible reduction in efficiency with use. In general the treated clays available for commercial use are more easily disintegrated and washed away than are the glauconites and synthetic zeolites. In consequence the treated clays are not usually selected.

The advantages of the base-exchange process using zeolites in comparison with the lime and lime-soda processes are: (i) it yields a softer water, with a hardness of not more than 1 part per 100,000; (ii) it automatically adjusts itself to variations in the hardness of the water undergoing treatment; (iii) there are no difficulties of precipitation and sedimentation; (iv) there is no problem of disposal of sludge; (v) the plant occupies less space; and (vi) it can be operated under pressure, thus avoiding the repumping sometimes required with the lime and lime-soda processes. Disadvantages are that: (i) the total concentration of dissolved solids in the treated water is greater than in the original water, whereas lime causes a reduction in the quantity of dissolved solids; (ii) the zeolites are not suitable for softening hot water above 40°C. or 50°C.; (iii) dissolved carbon dioxide is not removed and the corrosive action of the water may be increased; (iv) the alkalinity of the water may be unduly increased; (v) if the treated water is used in boilers at high pressure, the sodium bicarbonate in solution may decompose to give undesirable quantities of free carbon dioxide and caustic soda; (vi) compounds of iron and suspended solids and colloidal matter should be removed from the water before it reaches the zeolite, as otherwise the efficiency of the zeolite may be appreciably decreased; (vii) there is waste brine for disposal, although this only occasionally causes real difficulty. A decrease in efficiency has also been observed when the water has contained considerable quantities of free carbon dioxide as a result of the detrimental effect of the carbon dioxide on the zeolite; in such cases a large proportion of the carbon dioxide should first be removed.

Ion-exchange synthetic resins.—As a result of experiments made in

1934 at the Chemical Research Laboratory as part of the programme of the Water Pollution Research Board, it was discovered that resins prepared from certain phenolic substances and tannins possess marked base-exchange properties. The exchange value of some of these resins is a little greater than that of synthetic aluminosilicates, and they have the advantage that they are not destroyed by dilute solutions of acids such as sulphuric and hydrochloric acids or by dilute solutions of alkalis. They can be regenerated with a solution of sodium chloride to give a sodium compound which can be used in the same way as the aluminosilicates, or they can be regenerated with acid to give the hydrogen compound instead of the sodium compound. If hard water is treated with a base-exchange resin previously regenerated with acid, the calcium and magnesium in the water are replaced by hydrogen so that the bicarbonates and sulphates are replaced by dissolved carbon dioxide and sulphuric acid. Carbon dioxide can largely be removed by subsequent aeration. This means that water containing very little dissolved substances can be obtained from water in which the hardness is mainly caused by bicarbonates of calcium and magnesium. It was also discovered during the same investigation that resins prepared from certain aromatic bases possess acid-exchange properties. These resins also are not destroyed by dilute solutions of acids and alkalis; they are unique in that no other group of substance with similar acid-exchange properties has been discovered. Expressed in terms of chemical equivalents, the exchange value of the best of the acid-exchange resins is about twice as great as that of the base-exchange resins. This means, for example, that if one volume of the base-exchange resin previously treated with acid, is required to remove the calcium, magnesium or sodium from a given volume of a solution of the sulphates or chlorides of these metals, only 0.5 volume of the acid-exchange resin is required to take up the sulphuric acid or hydrochloric acid in the water treated by the base-exchange resin.

By utilizing a base-exchange resin and then an acid-exchange resin dissolved salts can be removed from natural waters to give a water approximately equivalent to distilled water.

Some of the results of the experiments with the exchange resins have been published in the annual reports of the Water Pollution Research Board, and in a paper by Messrs. B. A. Adams and E. L. Holmes¹. The use of these resins is protected by British Patents Nos. 450,308; 450,309 and 474,361; and by foreign equivalents. Several of the resins are in commercial use in various parts of the world for softening water, for the removal of salts to produce the equivalent of distilled water, and for the recovery of valuable materials from waste waters.

Carbonaceous base-exchange materials.—At about the time of the dis-

¹ "Absorptive Properties of Synthetic Resins." *J. Soc. Chem. Ind.*, vol. 54, p. Jan. 1935.

covery of the exchange resins, investigators in several parts of the world found that base-exchange materials similar in properties to the base-exchange resins can be prepared by treating carbonaceous materials such as coal and starch with strong sulphuric acid. The methods of preparation are covered by various patents. Considerable quantities of base-exchange materials made from coal are now in use on a commercial scale. In several instances the feed-water for high-pressure boilers is being prepared by treating the water from the usual source with carbonaceous exchange materials and exchange resins to produce water equivalent to that obtained by distillation.

Combination of methods.—From this brief review of the principal methods of softening water it is clear that the most suitable method in any set of circumstances can be selected only after full consideration of the purposes for which the treated water is required and of the results of chemical analysis of the water available. To meet particular requirements it is sometimes desirable to soften water by more than one method, or to treat part of the water by one method and part by another, and then to mix the treated waters in predetermined proportion.

CORROSIVE WATERS.

Some natural waters, especially very soft waters of moorland origin which are acid in reaction and contain appreciable quantities of dissolved carbon dioxide, have a marked corrosive action on iron mains, galvanized steel tanks, and lead service pipes. As a result they may become contaminated with iron, zinc, and dangerous quantities of lead before they reach the consumer unless they are adequately treated before distribution. In addition they may cause considerable damage to mains, tanks, and household pipes; they may also have some action on copper pipes and tanks. Though most of the highly corrosive natural waters are very soft, many hard waters are also corrosive, particularly those in which the hardness is mainly temporary and which contain much more carbon dioxide than is necessary to retain the bicarbonates of calcium and magnesium in solution. The action of different waters on the materials of mains and services has been studied by many investigators, but there is still a lack of exact information on the factors influencing the action and on the best methods and conditions of treatment of corrosive and plumbo-solvent waters.

The methods of treatment which have been employed include the addition of lime, chalk, soda, and sodium silicate in controlled quantities, the passage of the water through beds of limestone, marble, and magnesite, and the removal of dissolved carbon dioxide by aeration of the water. These methods increase the alkalinity of the water and most of them also reduce the concentration of free carbon dioxide; as a result they provide a treated water likely to deposit or form a protective coating

on the metals. At works at which constant control can conveniently be provided, the usual method is to add lime in measured quantities. Experience has indicated that this is the most satisfactory method of reducing the corrosive and plumbo-solvent action of the waters. It increases the hardness of the water, but only by from 1 to 4 parts per 100,000. In some circumstances, however, the necessary control cannot be provided at a reasonable cost; for example when the water is drawn by small undertakings from high moorland areas which are not easily accessible during part of the winter. In many of these instances the water has been treated at or near the source by passing it through simple channels or tanks containing limestone chippings. The channels or tanks should be covered to exclude light; otherwise growths of algae may occur on the limestone and prevent satisfactory reaction with the water. Even when the channels or tanks have been covered, however, deposits have been formed on the pieces of limestone, particularly when the water has contained colloidal peaty matter. In general this method of treatment has not been entirely satisfactory. Some of the unsatisfactory results may have been due to lack of information on the effect of the size of the particles of limestone and the rate of flow of the water. With the object of obtaining more precise information on the effects of these and other factors, the method is being investigated by the Water Pollution Research Board. The efficiency of the method of treatment is being measured by determination of the increases in the pH value, the alkalinity, and the hardness of the water, the reduction in the concentration of free carbon dioxide, and the reduction in the contamination of the water by lead after passage through and storage in lead pipes under standard conditions. The results so far obtained with a peaty moorland water, which is acid in character and has a pH value of about 4.5, indicate that the limestone chippings should be small, ranging from $\frac{1}{16}$ inch to $\frac{1}{8}$ inch in size, and that the rate of flow of the water through the chippings should not be higher than about 10 gallons per hour per cubic foot of limestone. With the particular water tried the limestone chippings require, at intervals of several weeks, vigorous washing to remove deposited peaty matter or replacement with new limestone. Experiments over long periods with other waters are required before very definite conclusions can be drawn.

IODINE.

The question whether deficiency of iodine in drinking water is a contributory cause of endemic goitre has long been the subject of controversy; the evidence collected is indefinite. It is probable that larger quantities of iodine are normally taken with foodstuffs than in drinking water. It may be, however, that in districts in which the water-supply is poor in iodine, the local foods are also deficient in this element. In some districts abroad, in which goitre is prevalent, iodine has on occasions been added

as sodium iodide to the water-supply. The use of iodized salt in place of common salt for household use has also been recommended.

FLUORINE

In some districts the water-supplies contain abnormal quantities of fluorine—4 or 5 parts per million. There is evidence that quantities of fluorine of this order give rise to the prevalence of the dental defect known as mottled enamel. The subject has received considerable attention, particularly in America, during recent years, and many methods of treating the water to reduce the concentration of fluorine have been tried. Treatment with calcium phosphate seems to have been one of the most successful methods. The opinion has been expressed that some fluorine is necessary and that if the concentration in drinking water is too low—well below 1 part per million—there may be prevalence of dental caries.

It is evident that in the future much more attention will have to be given than hitherto to those constituents of water which may be present in minute concentration.

In this Paper an attempt has been made to review briefly some of the problems and methods of treatment of water for various purposes, particularly for public supply. In the space available it has not been possible to mention all the problems and methods, nor to discuss any one of them in much detail. The Paper will have achieved its main object, however, if it stimulates interest in the subject and thus leads to further investigations and progress in the future.

Discussion.

The Author said that he greatly appreciated the honour accorded to him by The Institution in inviting him to read a Paper on such an important subject. He realized that he had undertaken a formidable task, because he was asked to deal with the subject in a broad way covering the bacteriological side, growths, hardening, softening, and other matters: in fact it was a request almost for an *Encyclopaedia Britannica* of water treatment. He had done his best to keep the Paper within reasonable limits. Each section might well be extended to form a long, separate Paper, and no doubt a number of points had not been touched upon at all.

In his reference to the work of the Geological Survey he had perhaps understated what had really been done. During the past 5 or 6 years the Geological Survey had collected a very large volume of valuable information on underground water resources, some of which had been already

published in "Water-supply Memoirs." Much more had been recorded, and he hoped that after the war it would be published.

The position with regard to surface water was not quite so good. The Inland Water Survey began its operations a few years before the war, but owing to war conditions the work had had to be curtailed. He hoped, however, that it would be intensified and would cover a much wider field after the war.

The President observed that the Paper was intended to cover in a general way the numerous problems which arose in connexion with water-supply and purification, and he thought it would be agreed that the Author had achieved his object admirably.

Mr. W. J. E. Binnie said that it gave him great pleasure to take part in the discussion owing to his association with the Author as a member of the Water Pollution Research Board. The Paper was of great value and covered many aspects of the subject, including water survey, the vital importance of which had not been recognized by Parliament or by the general public—in contrast to the attitude in some countries, where large sums were contributed annually by the State to enable the necessary information to be elicited. So long as the research was left to a body which had no money at its disposal to enable it to establish and inspect the necessary gauges the information obtainable would be scanty. In his view the best solution would be to place the survey under the Department of Scientific and Industrial Research, allocating a sufficient annual sum to the work.

As the Author had pointed out, British rainfall statistics were ample although practically all of the information was contributed by voluntary workers. It cost very little to put up a rain-gauge, but the establishment of a river-gauge was another story. Once the gauges were there, however, Mr. Binnie felt confident that voluntary workers would be found to read them and send the information to the central authority to be embodied in annual reports.

The average annual run-off from a catchment-area could be estimated from the rainfall and the extent of the area after making a deduction for loss by evaporation, etc.; but that deduction varied widely in different areas of the British Isles, depending largely upon the hours of sunshine and the temperature and humidity of the atmosphere at the particular locality. When a local authority applied to Parliament for powers to abstract water from a stream, the construction of a reservoir was usually contemplated from which compensation water was to be furnished, and frequently no gaugings of the actual flow of the stream were available. The compensation water was therefore based upon the average annual run-off from the catchment-area during the driest three consecutive years, and in estimating the run-off a deduction of 14 or 15 inches had been taken as representing the annual difference between the rainfall and the run-off; but Mr. Binnie's experience had shown that it varied from 10 inches to 22 inches. Under-estimation of the deduction to be made might have serious consequences.

quences if the average annual rainfall were low. In one case within his knowledge the actual run-off was so much lower than had been estimated that the water authorities could maintain only half the quantity for supply which they had been led to expect after deduction of the compensation water.

In the cases of several bills which were approved by Parliament it was acknowledged that uncertainty existed as to the quantity of the average annual rainfall, and the appointment of an independent arbitrator was sanctioned to establish the necessary gauges and determine the value to be adopted after the lapse of sufficient time to enable an estimate to be formed. In the case of at least one Act a "tentative" value was also given as representing the deduction to be made from the rainfall in ascertaining the run-off—that value to be subject to review when the necessary information had been obtained. The proportion of the true run-off which was to be given to the river as compensation water was determined by the Committee, but no actual quantity was stated. That procedure might well be followed, as it ensured that the correct quantity of compensation water was given to the river.

In the absence of a storage reservoir to equalize the flow of a river, an industry or power-station was dependent upon the minimum flow for its supply of water. The minimum flow of a river was independent of the average annual rainfall, as it represented the quantity of water which entered the stream from ground storage when there was little or no rainfall in the neighbourhood. That ground storage was governed by so many factors that it was impossible to estimate it, and his own experience had shown that in extreme dry weather the run-off from one catchment might be ten times greater than it was from another. Gaugings over a sufficient period were therefore essential in such cases to establish the correct minimum flow; in their absence the grossest errors had been made, which had led to the establishment on the banks of a river of works requiring far more water than could be obtained in dry weather.

The improvement in the method of treatment of sewage by means of percolating filters was largely due to the work of Mr. H. C. Whitehead, M. Inst. C.E., who was also a member of the Water Pollution Research Board. The problem was of great economic importance, and Mr. Binnie hoped that Mr. Whitehead would enlarge upon it during the discussion.

He agreed completely with the Author's statement that "So many factors have to be considered that, although certain broad principles have been established, the best conditions and the best coagulant or mixture of coagulants for any particular water can be determined only by experiments with that water." He would add that analyses of water taken from a flowing stream might be entirely misleading as an indication of the character of the same water after storage in a reservoir. When designing purification works engineers should bear that in mind, so that works could be readily adapted for alternative methods of treatment. For instance,

although analysis of stream water might indicate that there was little or no trace of iron, yet trouble might arise from that cause after storage, calling for the adoption of aeration ; or unpleasant taste and odours might occur, necessitating the addition of activated carbon.

The information given in the Paper as to the troubles caused by algae and weeds was very valuable. Trouble with weeds was pronounced in shallow reservoirs, as many water engineers knew to their cost. Some engineers had advocated liming the beds of reservoirs before storage commenced, the quantity of lime prescribed being $1\frac{1}{2}$ ton per acre. That treatment was rather costly, especially in the case of a reservoir of very large extent, and he would appreciate the Author's views on the subject.

The Author had stated that previous filtration through rapid filters enabled the adoption of a rather higher rate of filtration through slow sand filters. Mr. Binnie would suggest amendment of the word "rather" to "considerably." Doubtless some members present could give their experience with regard to that important point.

With regard to the action of corrosive waters on metals, in about 1909 the question of deterioration from deposits was referred to a Committee in which the late Sir William Ramsay took the most active part, and he expressed the opinion that if the gases were removed from such water it would become inert on metals. That was found to reduce the corrosive activity of the water to one-sixteenth of what it had been before. The apparatus for removing the gases was easy to work, and the cost was only about $\frac{1}{4}d.$ per 1,000 gallons. The Western Australian Government, which had experienced trouble with its water-supplies, was advised to adopt that treatment, but it did not take the advice, preferring to put in lime instead ; but at least it adopted the plan of aeration. The results were not quite so good as those obtained with the experimental plant, but they were very near.

Dr. H. T. Calvert observed that the Paper was particularly valuable as it opened avenues for co-operation between the engineering sciences and the biological, chemical, and medical sciences. It was only by such co-operation that progress would be made. Those various sciences were adequately and well represented on the Water Pollution Research Board, and that, he thought, was responsible for the success of the Board since its inauguration.

With regard to the inland water survey, he thought that it was not of much use to carry out such a survey merely to pigeon-hole the data which were collected. They should be utilized, and those who collected them should know how to utilize them and to see that they were properly utilized. As the Author had pointed out, those data were to be the machine-tools for planning in the future, and Dr. Calvert hoped, with Mr. Binnie, that they would be properly collected. He would not enlarge upon Mr. Binnie's suggestion that the Department of Scientific and Industrial Research should be responsible, nor would he say that he agreed with it.

He thought that the success of the Royal Commission on Sewage Disposal was due very largely to the fact that it did not confine itself to the taking of evidence, but also conducted experimental work which had proved of fundamental value. He hoped that the Water Pollution Research Board might be regarded as the successor to the Royal Commission so far as that part of the Board's work was concerned. He hoped also that the Author would amplify his statements as to the doubtful value of chloramine for preventing growths of algae or the effectiveness of so-called cupri-chloramine.

Mr. H. F. Cronin wished to endorse the Author's remarks regarding the prevention of pollution, especially of overground sources of water. The water resources of Great Britain were rather limited, and a greater demand for water was bound to arise in the future, with the consequence that more overground sources would have to be used.

With regard to algal growths, the Author had stated that copper sulphate should be applied just before they became prolific. The trouble was to know when the growth was about to become prolific. The algal growths in reservoirs paralysed the filtration-plant, especially during the early part of the year. Why some storage reservoirs were good as regards algal growths and some were bad was a difficult question to answer. Certainly the construction of the reservoir appeared to have some bearing. In the case of a reservoir bank lined in two ways—on the top with concrete block pitching, about 2 feet 9 inches long and 9 inches wide, and lower down with slabs cast in situ—it had been found that the concrete blocks permitted a tremendous growth of weeds and probably helped the growth of algae.

In his opinion filtration was the most important purification process, because it was the one in which a final barrier was placed before the bacteria in the water. Other processes of purification, such as chlorination and ozonization, depended upon the application of some outside substance to the water, and if the apparatus stopped or broke down, or there was carelessness on the part of the attendant, the water might not be properly purified.

The Metropolitan Water Board had recently—that was, within the past 20 years—introduced a combination of rapid filters and slow sand filter-beds, the former using no coagulant. The combination of rapid filters and slow sand beds, whilst it admittedly had defects, was of great importance, and had enabled more water to be filtered at a lower capital cost and a smaller running cost than slow sand beds only. Admittedly filtration works were expensive from the capital point of view, but the actual cost of filtration to the Board was about 19s. 6d. per million gallons—that is to say, the quantity filtered in the year 1938–39 was 95 thousand million gallons at a cost of £93,000. When it was remembered that 1 million gallons of water was worth, including the interest on capital and rates, etc., about £50, the filtration cost was only about 2 per cent.

It had been noticed that after washing primary filters sand came over

into the drains in fairly large quantities, but the extraordinary thing was that although the sand continued to come over, the level of the sand in the filter-bed did not fall. The Water Investigation Department of the Board therefore investigated the matter. It was found that the grains of sand, instead of being sharp, were round, being coated with calcium carbonate. The coating was removed by the addition of weak hydrochloric acid, and the reduction in volume amounted to about 40 per cent. This was rather a serious problem, as one could not treat sand in a concrete filter-bed with hydrochloric acid, and it seemed that the sand would have to be renewed periodically. It would be interesting to know the experience of other undertakings in that respect. If coagulation was used, did the sand-grains grow in the same way?

The performance of one of the filtration works at Kempton Park was illustrated by lantern slides, showing the quantity of water filtered and the area cleaned per month, and the numbers of filter-beds which had to be cleaned at different periods were compared. The first high peak, that was, heavy cleaning, was in July 1930, and others occurred in February and March 1931, in April and May 1932, and in March 1933. A "good" period followed, with a very high peak in May 1936, and another high one in April 1937. March and April 1938 were high, as also were the same months in 1940. All were spring months, and they corresponded to the period when the growth of algae was greatest. Another slide showed what happened during a period of frost. As soon as the filter-bed was empty the sand froze. Ice accumulated to a thickness of 3 inches or 4 inches, and cleaning filter-beds under those conditions was extremely difficult, and it usually resulted in not very good water being obtained from the filter-bed.

The construction of slow sand filter-beds had often to be undertaken in waterlogged ground because it was necessary to install the bed at a low level to save pumping; and in Mr. Cronin's experience the failures or bad samples obtained from slow sand filter-beds could nearly always be traced to infiltration of ground-water, and not to any failure of the filter-bed to act as a filter-bed. In one interesting case practically sterile water was put on to certain filter-beds and very bad results were obtained. After a number of investigations had been made, it was found that there was considerable infiltration of ground-water.

The Author had commented upon the cost of installation and operation of small domestic water-softeners. Mr. Cronin lived in a very hard water district, and at his home he had installed a base exchange water-softener. It had a capacity of 800 gallons between washings, and in six months it softened about 35,000 gallons, using 476 lb. of salt, at a cost of 20s. 6d. That was not a very large sum, but it represented a rate of 6·9d. per 1,000 gallons. The wash-water, that was, the water used for regeneration and running to waste, amounted to 13 per cent. of the total.

Dr. E. B. Bailey said that the Geological Survey had utilized every opportunity to collect and publish data regarding underground water

supply. In 1935, when the Inland Water Survey Committee was established, a special water unit was instituted at the Geological Survey, under Mr. F. H. Edmunds, and additional staff was recruited. At the outbreak of hostilities the importance that would attach to anything to do with the distribution of underground water supplies was realized, and it might be said that the Geological Survey had done twenty times as much in collecting and distributing hydrogeological information as it would have done in a similar peace period. Much of that work was of a confidential nature, and would be of great value to the enemy; nevertheless, a good deal of information had been published in the form of pamphlets having a strictly limited circulation. It was fair to say that any inquiry regarding underground water which reached the Geological Survey was half answered at the time it was asked because so much had been collected.

Several thousand analyses had been filed in such a way that any inquiry regarding the composition of the underground water of a particular district could be dealt with at once.

Problems concerning the chemistry, physics, and physiology of extreme dilutions were particularly fascinating. Dr. Bailey agreed that a little fluorine was helpful, but there was little doubt that more than a certain quantity seemed to introduce difficulty. It affected the teeth, and in still larger quantity affected the bones and produced very painful results. Fluorine could be extracted from water by passing the water over calcium phosphate. It had been established for some considerable time that that was happening in nature. Fossil bones, some of them as much as three hundred millions of years old, had been analysed, and it had been found that, roughly speaking, the fluorine-content increased in accordance with the geological age of the fossil.

One of Dr. Bailey's colleagues, Mr. C. E. N. Bromehead, had devoted considerable attention to the problem of fluorosis from the geological point of view, and had supplemented the research on the medical side by a very useful geological sidelight. He had found, in co-operation with Dr. D. C. Wilson, that ground waters in districts where fluorosis was more marked than usual very often came from deposits which contained a considerable number of fossil bones or coprolites. That tended to show that the capture of the fluorine was a reversible process and that under certain surface conditions those bones, after having attracted fluorine to themselves through the ages, were capable of returning it into the water circulation.

Mr. Philip Porteous observed that he wished to support the Author's plea that the work of the Geological Survey and the Inland Water Survey Committees should be resumed, and speeded up if possible, with adequate financial backing from the Treasury at the earliest possible moment. It was, he thought, a fact that a number of statutory water authorities were rather reluctant to publish information in regard to the yield of wells and the underground water-levels, for the very good reason that, as the law stood at present, they had absolutely no protection against poaching on

their underground water-supplies. He would not labour the point, but he suggested that a very simple piece of legislation designed to protect water authorities against such a danger would have the effect of releasing a considerable body of valuable information relating to underground sources of supply.

It was, perhaps, worth noting that whereas more than 5,000 rain gauges had been established in the British Isles, percolation was measured at only six stations. It was very useful to know not only what the rainfall was, but also what proportion of that rainfall was going to percolate into the natural underground reservoirs in the permeable formations. Percolation-gauges were simple and inexpensive to construct, and the information they yielded was of great value.

He hoped the time was not far distant when the process of water softening would be regarded rather as an economical necessity than as a luxury. About 7 years previously the Cambridge Water Company had installed a base exchange softening plant which reduced the hardness from 23 parts to 11 parts per 100,000 before distribution to the consumer. The inclusive cost of that process was 1.3d. per 1,000 gallons, or 10d. per head of the population supplied per annum. Mr. Cronin's figure of 6.9d. per 1,000 gallons for salt alone underlined the obvious point that it was much more economical to soften the water centrally than in individual households.

To any water authority which sought to buy popularity with their consumers by softening water it should be pointed out that such popularity was likely to be very short-lived. Experience in Cambridge showed that after a year or two people began to say, "You are not softening water anything like as much as you used to do"; and that went on until of late it had been rumoured that as a measure of wartime economy the Company had ceased to soften water at all, whereas the fact was, of course, that they had been softening it to the same degree all the time.

With synthetic zeolite the weight of salt required in regenerating varied in proportion to the bulk of the zeolite provided; in the Cambridge plant it had been found that it paid handsomely to use what was regarded as an excess of zeolite in order to reduce the consumption of salt. At present the $\text{NaCl} : \text{CaCO}_3$ ratio was a little less than 2 : 1.

The water engineer to-day was liable to find a fair-sized military encampment established on or near his gathering-ground without notice. The efficiency of the military latrine was usually judged by the rate at which its liquid contents could be induced to percolate into the underground strata, and that type of pollution had not passed unnoticed by certain public water-supply authorities during the past two years. Had that been brought to the notice of the Water Pollution Research Board, and, if so, had they been able to induce the military to adopt something like a safe and sanitary field latrine?

Dr. W. G. Moffitt agreed that it was important that chlorination should be regarded only as an additional safeguard. In the first place,

everything must be done to keep the water free from pollution, and it should be brought to a state of purity before chlorination was applied. The Author had referred to the corrosive action of softened waters. Corrosion often occurred also when large institutions used softened water in a hot-water system, and in Dr. Moffitt's experience trouble had been encountered owing to such corrosion. It would be more satisfactory if water of high temporary hardness could be softened at the works rather than at a series of separate points, and in that way the corrosion difficulty would be remedied.

Mr. Julius Kennard wished to congratulate the Author especially on having dealt with so wide a subject without introducing a single chemical formula. During some years Mr. Kennard had been privileged to act as an abstractor for The Institution, and almost every week he had received American literature containing results of extensive research, descriptions of new treatment plants, and detailed accounts of operating experiences. It was extraordinary that, although filtration was first introduced by Great Britain in 1829, when the London supply was treated by slow sand filters, the principal developments had occurred abroad—notably in the United States.

Towards the end of the last century considerable experimentation was carried out by chemists and bacteriologists, after which the engineers took up the matter from a practical standpoint; and he would strongly recommend all engineers who were interested in the subject to consult The Institution's "Engineering Abstracts" (unfortunately suspended during the war), where they would find a wealth of information dealing with the subject.

So far as chlorination was concerned, there could be no doubt that the rapid progress which had been made in sterilizing supplies since the regrettable epidemic at Croydon a few years ago was continuing; yet only a few months before the outbreak of war, during a discussion at the Institution of Water Engineers, some engineers in charge of considerable water undertakings had expressed the view that it was unnecessary to introduce chlorination in the case of supplies which had been beyond suspicion for many years. One speaker had mentioned the analogy of motor-car insurance, and had pointed out that cautious motorists had insured against risks of accidents long before Parliament had made insurance compulsory. Mr. Kennard considered that chlorination should be regarded as an insurance against pollution, and he agreed with the Author that after introducing chlorination it was quite wrong to sit back and relax all efforts against contamination—just as no sensible motorists, because they were insured, would relax their vigilance against accident. Many instances of pollution had occurred even after the water had been chlorinated, particularly in cases where it had been stored in open service reservoirs.

In connexion with the difficulties caused by algal growths, he wished to refer to an experience of Mr. Philip Porteous, M. Inst. C.E., which occurred

at a reservoir in the West of England about eleven years ago¹. The reservoir was lined with precast concrete blocks and had a maximum depth of 35 feet. Dense masses of *chara* were discovered 15–20 feet below water-level. The reservoir was dosed with copper sulphate at the rate of 0.45 part per million, but at the end of a month the growth continued to flourish. Potassium permanganate was tried, but not until the dose was increased to a point at which the water was discernibly pink did the permanganate diminish the taste. Eventually activated carbon was distributed on the surface at the rate of 5 parts per million, which gave an impression at first that the reservoir contained black ink; but within 48 hours the carbon had settled to the bottom and the brackish taste and odour had disappeared. The cost at that time worked out at just under $\frac{1}{4}d.$ per 1,000 gallons treated.

A method of treatment in addition to those mentioned by the Author was to spread the copper sulphate in a fine crystalline form from a specially-designed blower giving a uniform vertical distribution which could be varied according to the concentration and depth of treatment desired. That method was stated to be more economical in regard to material, time, and labour.

In the past engineers had concentrated rather upon immunity from the danger to health which followed the use of untreated water, but now attention was being devoted more to the physical appearance, the hardness, the corrosive properties, and the fitness of the supply for industrial use.

Recent meetings at The Institution had indicated a growing appreciation of the aesthetic characteristics of engineering, and the subject of water-supply was no exception.

Mr. A. C. Gardiner observed that theoretically he was in complete agreement with the Author's dictum in connexion with algal problems, that prevention was better than cure—he said “theoretically” because experience reminded him of the further dictum, that “What can't be cured must be endured.” It was, of course, practicable to kill many species of algae with a dose of from 0.5 to 0.6 part of copper sulphate per million, but the first species might well be succeeded by a second which was much more resistant.

Some years ago a small reservoir was treated as an experiment with 2.2 parts per million of copper sulphate, to combat a growth of the diatom *Fragilaria*. The effect was immediate and the water became clear, but within a few days one of the small green algae appeared and increased to such an extent that the water became grass green, and a man's hand disappeared from view a few inches below the surface. That condition persisted for 6 weeks, although the concentration of copper sulphate did not fall below 1.6 per million.

The destruction or reduction of algal growth in a reservoir did not necessarily stop the development of sessile algae (chiefly diatoms) on the

¹ Trans. Instn. Water Engrs., vol. xxxvii, p. 305 (1932).

surface of sand filters, and that might soon be so great as seriously to impede filtration. He could recall instances, particularly in the early part of the year, when filtration troubles were quite acute owing to the sessile growths, despite the fact that the water in the reservoir was of good quality.

He would be the last to deny to copper sulphate a very useful place in water treatment, but much information of practical value could be obtained from a close study of the seasonal occurrence of algae in reservoirs. The Author had mentioned that periods of high algal production were to be expected from the beginning of April to the beginning of June, and again from the end of August to the middle of October. Mr. Gardiner wished to amplify that statement. He believed that in a particular reservoir the same species of algae would tend to appear each year at much the same dates in a particular reservoir; but that would not hold good for a number of different reservoirs, even if they were situated quite close together and fed from the same source of raw water. In the years 1940, 1941, and 1942 the maximum production of diatoms in one Thames reservoir occurred on the 19th, 25th, and 31st March, whilst in another reservoir, situated only a few miles away, and also fed from the Thames, the maximum production of diatoms in 1941 and 1942 occurred on the 15th and 21st April; in another reservoir in the same area the date of the spring maximum was even later.

It might be said that it was cold comfort to know when to expect filtration troubles: but that was, perhaps, better than not to know at all.

The Author had referred to the rapid rate of increase of algal populations. Mr. Gardiner believed that practical information could be obtained gradually. Progress would be slow because it would probably be found that the standing crops of different species of algae, and even of different species of diatoms, did not increase at the same rates. Moreover, the probable rate of increase of a particular species in the London reservoirs would not necessarily hold for other bodies of water. Especially would that be so where the levels of concentration of dissolved nutrient salts were different. In some London reservoirs standing crops of the diatom *Asterionella* roughly doubled themselves each week during the spring until the maximum was attained. Daily observations made in 1942 had shown that the crops increased exponentially right up to the day on which the maximum occurred, and then decreased rapidly. Daily estimates of the number of those diatoms per litre of water ranged themselves in a series in geometrical progression with a common ratio of 1.08.

Gradual accumulation of such data should enable not only the date of maximum production to be forecast, but also the level of concentration; and that, coupled with a knowledge of the filtration difficulties likely to arise from known concentrations of the particular species, should enable decisions as to remedial measures to be made some weeks ahead. The relatively low rate of increase of the diatom *Asterionella* was not common to

all species. Standing crops of the particularly troublesome, though minute, diatom *Stephanodiscus Hantzschii* tended to double their number daily rather than weekly.

In Mr. Gardiner's view, one function of the waterworks biologist was to collect such information as would enable him to forecast the probable sequence of events in the reservoir, in order to plan the necessary remedial measures a few weeks ahead.

* * Mr. H. C. Whitehead considered that the Paper would form a valuable work of reference for all who were interested in water, and in the problems of its use.

A growing similarity was apparent between the work of some waterworks engineers and others engaged in the purification of sewage; and with the greater spread of population and industry over rural areas, it might be expected in time that future engineers of the Metropolitan Water Board would be compelled to take more than a passing interest in sewage purification, and in possible methods of augmenting London's supplies by, say, pumping 50 million gallons daily of effluent from the Mogden sewage purification works of the Middlesex County Council to the headwaters of the Thames!

The re-use of water for domestic and industrial requirements was more general than most people imagined, not only in England, but also in all parts of the world where water-supplies were taken from rivers. In Great Britain much more could be done in rivers draining industrial areas to improve the quality of the used water before its departure for further use down stream.

He had in mind those industrial areas situated on the upper reaches of streams; for example, the Potteries at the head of the Trent, Birmingham and the Black Country area at the head of the Tame, and other industrial areas in Lancashire and Yorkshire. However well those areas were sewered and served by sewage-purification works, every heavy shower of rain brought polluting matter to the river.

During such storms the river Tame below Birmingham and the Black Country had, at certain periods, contained four times as much suspended matter as was usually present in crude sewage. That suspended matter was deposited in the middle and lower reaches of the river, and by its subsequent fermentation exerted a depressing effect upon the oxygen content of the river water for many weeks after the storm.

Impounding reservoirs or lakes could, in most instances, be constructed below the principal industrial areas; and if the removal of sediment were carried out regularly, that provision would ensure that the middle and lower reaches of rivers like the Trent and the Tame would once more be restored to first-class condition for fishing, and the re-use of water for all purposes would be made safer and more general. That method of river

* * * This contribution was submitted in writing.

water treatment had been in successful use in the Ruhr district of Germany for more than 14 years.

The Author, in reply, observed that there was clearly complete agreement with his view that intensive surveys of the water resources of the country should be undertaken as soon and as rapidly as possible if there were to be satisfactory planning of towns, industries, and urban and rural areas. The surveys should include the collection of comprehensive data not only on the quantity but also on the quality of the water from the different sources. He was glad that Dr. Bailey had mentioned the great extension during the past three years in the work of the Geological Survey in the collection of data on underground water resources, and he hoped that that work would not be curtailed after the war. Unfortunately, the collection of information on the flow of water in lakes, rivers, and streams, which was begun in 1935, had been restricted. Mr. Binnie had given some excellent examples of the difficulties which had arisen and the mistakes which had been made, owing to insufficient information on the water resources; other similar examples could be given.

Several contributors had referred to the difficulties caused by growths of algae and weeds in reservoirs and other bodies of water. Mr. Gardiner had reviewed the factors to be considered in the difficult problem of prevention of the growths. Only the broad principles of the methods available for dealing with that problem could be stated, as each body of water had its own special characteristics and required separate study if the most suitable conditions of treatment in each case were to be discovered. Mr. Binnie had stated that some engineers had advocated placing limestone on the bed of reservoirs before filling the reservoirs with water. It was the Author's impression that the limestone was usually intended primarily to neutralize acid moorland water and to reduce the concentration of free carbon dioxide in waters containing excessive amounts of that gas. It was doubtful whether the limestone had any marked effect in preventing growths of algae and weeds, and in most instances it had little effect under such conditions on the acidity of the water. In reply to Dr. Calvert, the Author personally had not compared copper sulphate with so-called cuprichloramine for the prevention of algal growths, but the experience of others seemed to indicate that cuprichloramine was no more effective than the corresponding dose of copper sulphate. Mr. Kennard had mentioned the application of copper sulphate as a powder or as very small crystals distributed from equipment specially designed for the purpose. That method of application probably had advantages in the treatment of very large bodies of water. Mr. Cronin had mentioned a reservoir in which growths had been more prolific above concrete blocks than above slabs cast in situ. The conditions above those two areas, however, might not have been otherwise identical. For example, there might have been differences in the depth and circulation of the water and in other conditions likely to affect the extent of the growths.

On the subject of filtration through sand, Mr. Cronin had given an example of contamination of sterile water during passage through slow sand filters, owing to the influx of non-sterile ground water. It was important to take every possible precaution to ensure that water other than that undergoing controlled filtration could not find its way into the filter, even if that meant raising the level of the filters and extra pumping. Increase in the size of the grains of sand by growth of deposits of calcium carbonate on the grains had been observed by many water engineers, and that trouble had been discussed in some detail in a number of published Papers. It seemed fairly certain that the deposition was caused by the loss of free carbon dioxide, which resulted in reduction in the solubility of the calcium carbonate responsible for temporary hardness. It was doubtful whether the use of coagulants would reduce the quantity of calcium carbonate deposited in the filter, though there was the possibility that in the presence of a coagulant the carbonate would be deposited in a form more easily removed on back-washing the filter.

Mr. Cronin's figure of 6·9d. per 1,000 gallons for the cost of salt for the regeneration of a household water softener was interesting. In addition, the total cost of the softening in those small household softeners should include an amount, which in some cases might be as much as 12d. per 1,000 gallons, to cover the capital cost and depreciation of the equipment. The overall cost, quite apart from the inconvenience of operating the softener, might thus be of the order of 18d. per 1,000 gallons with very small softeners. A comparison with the figure of 1·3d. per 1,000 gallons given by Mr. Porteous for the cost of softening by a similar process, but on a large scale, at the works of the Cambridge Water Company was instructive and confirmed the Author's view that it was preferable, and much less costly, to soften hard water at the water works than in numerous small softeners on consumers' premises.

As indicated by Mr. Binnie, the corrosive character of many natural waters could be entirely or largely removed by removing the dissolved gases, oxygen and carbon dioxide. Except in special circumstances, it was impracticable to remove both dissolved oxygen and carbon dioxide. The usual method of reducing the corrosive character was to reduce the quantity of free carbon dioxide by addition of lime, or treatment with limestone, or by aeration. By those methods the quantity of so-called corrosive carbon dioxide was reduced and the probability that the water would form a protective coating on metals was increased.

The Author agreed with Mr. Whitehead that it would be necessary for water engineers in future to take much more interest in methods of treatment of sewage, and he would add also trade effluents, because many rivers from which water was drawn for treatment and distribution received sewage or sewage effluents and trade effluents. Mr. Whitehead had referred to the River Ruhr, in Germany. That river received sewage effluents and trade effluents. By means of infiltration galleries, water was

drawn from the river for treatment and distribution to a large population. It was estimated that during one long period of drought some years before the war, the cycle of water-supply from that river, sewage effluent to the river, and back to water-supply, on the average was completed about three times before the water passed on down the river below the infiltration galleries.

After the meeting Dr. H. Ingleson, of the staff of the Water Pollution Research Board, demonstrated the removal of salts from saline water by treatment with the new base-exchange and acid-exchange resins, and explained the method employed for determining the average concentration of lead in water withdrawn from individual household taps over periods of several weeks or months.

Correspondence.

Mr. S. B. Jackson observed that the Paper provided an opportunity of considering water conditioning in generating-stations employing high initial steam conditions in reference to new methods now available. It was not fully appreciated that of the two raw materials required for energy-production—coal and water—the status of the latter was by far the more important.

Assuming a modern high-pressure, high-temperature base-load station of 300,000 kilowatts, maximum continuous rating, operating at a load-factor of 60 per cent., the annual coal requirement was 725,000 tons, but the annual water through-put was 6,250,000 tons, with a make-up of 125,000 tons. Those figures placed in correct perspective the relative importance of the two primary commodities. Considering the capital costs of what Mr. Jackson preferred to term the handling and conveyance equipment, on the basis of pre-war prices, an analysis of tenders for six large modern stations, showed :—

	£ per kilowatt.
Coal-handling and storage	0.45 to 0.50
Coal-bunkers and chutes	0.20 to 0.40
Ash-handling plant	0.25 to 0.45
	<hr/>
	0.90 to 1.35

the average being £1 15s. per kilowatt, or £0.46 per ton of coal to be dealt with annually. The cost of the water-handling and conveyance equipment, including filtration, lime-soda softening, evaporators, feed system, steam range, and boiler chemical conditioning, was £0.50 to £0.75 per kilowatt, giving an average of £0.6 per kilowatt, or only £0.03 per ton of water

throughput annually. Thus the capital cost of water conditioning and conveyance was only one-fifteenth that of coal- and ash-handling when expressed on a throughput basis. In view of the greater importance of correct water treatment upon the performance of the plant, maintenance and outage, it would seem that probably an undue parsimony had been allowed to obscure the real perspective of the design of generating-station water-conditioning plant, and that the provision of modern co-ordinate water-conditioning could be made at relatively low cost, and was an investment of considerable value. .

Another aspect was the cost of evaporator losses due to blow-down radiation, and convection. It had been tacitly assumed that the evaporator had worked at 100 per cent. efficiency, and such losses had been conveniently neglected. In the station reviewed those losses cost 310 tons of coal annually, which, at pre-war fuel prices and water costs, would represent £325, the capitalized value of which for average electricity undertakings was approximately £5,500. Thus evaporation was probably the most costly method of water treatment; moreover the elimination of such losses produced a very small increase in *useful* boiler capacity, which having been paid for to produce output, was used to evaporate raw water. Thermodynamically there was little, if any, justification for evaporation.

It could be shown that improvement in plant item efficiencies yielded a satisfactory cumulative result upon the overall plant performance; and any improvement of individual component efficiencies, or the elimination of inefficient components, was a trend to be welcomed.

The evaporation loss could be eliminated whilst providing high-grade boiler feed by the "Deminrolit" process, which was of the carbonaceous and resinous type referred to in the Paper. He had recently inspected two of such plants in operation in high-pressure stations. The simplicity of the plant, its reasonable capital cost in relation to its functions, the very low operating costs, and the fact that it could be operated by unskilled labour rendered it an eminently desirable unit in electric power-production. The effluent produced was of zero hardness and of high purity, as expressed in terms of conductivity. More than 95 per cent. of the original dissolved solids, such as lime, magnesia, sodium bicarbonate, and sulphates, could be removed without being substituted by any other chemical. The plant dealt satisfactorily with waters containing humic and other acids of organic origin, and more than 95 per cent. of carbon dioxide could be eliminated whilst such residual as remained could be easily fixed by 0.45 part per 100,000 of caustic soda. Entrained oxygen or carbon dioxide introduced during storage could be dealt with by the de-aerator or the condenser. He had been informed that no boiler outage of any kind attributable to the feed water supply had occurred since the installation of the plants.

The high degree of control permitted by the process enabled reduction of hardness, total dissolved solids, and alkalinity to any desired value. The final alkalinity might be adjusted and maintained to accommodate the

particular station boiler conditions required ; and such flexibility was an important chemical and operational factor, especially when the initial water quality might be variable. Ammonia salts and free ammonia in gaseous form were also removed by the process ; and as such removal could not be effected by the conventional lime-soda and evaporator combination, the process would probably assume greater importance in future high-pressure steam-generation.

The operating cost was controlled by the composition of the water treated, the cost of sulphuric acid and soda ash, and the final quality desired. It was regarded as reasonable in view of the particularly filthy waters dealt with, and especially as those waters would require ancillary treatment if the conventional lime-soda and evaporator treatment were installed. The cost of heat-losses of evaporation were eliminated, and the resulting water was of high grade and very suitable for boiler-feed. With evaporators the deterioration of performance following the formation of scale on the coils caused priming. Whilst it was difficult to assess the complete causes of priming, the composition of the boiler feed was a major influence, but the provision of a non-heated chemically pure feed and the elimination of evaporator carry-over were definite contributory factors to improved high-pressure boiler operation. The unreliability of evaporators in the production of a feed of uniform quality indicated as a first essential their removal from the cycle.

On the basis of the detailed cost analysis of the stations referred to, the adoption of co-ordinated boiler-feed conditioning, including chemical proportioning, still regarding the conditioning and conveying equipment as a whole, would result in a capital saving of from 5 to 7.5 per cent. in comparison with the lime-soda and evaporator scheme, provided that the installation was designed solely to participate in the full advantages of the new process. From such an aspect it appeared that the capital and operating economics of the method were attractive and that the piecemeal design of water conditioning equipment was to be deprecated.

Mr. Jackson therefore felt that an important advance in feed-water treatment had been made.

Mr. W. N. McClean observed that river measurements and records were the principal items of an Inland Water Survey. The flow of rivers had to be measured accurately with apparatus for recording water-velocities at determined points throughout a water section, at all stages of the river. The apparatus for a particular river site might have to be designed specially ; but in Great Britain the ropeway and suspended meter would usually suffice, except for velocities below 3 or 4 inches per second.

During the flow-gauging, and also afterwards for correct records, water slopes had to be measured in various ways. The established gauging-station was no single-point affair in the majority of cases. Floods and low flows might have to be gauged at different sites, with accurate correlation of levels ; and it might even be necessary to carry out some control work

in order to stabilize a river reach. The work should be carried out by trained surveyors, under a central executive organization.

In the United States of America, 400 or 500 such surveyors worked under the supervision of the Geological Survey Department, with apparatus designed and tested by the National Bureau of Standards.

In August 1939, when visiting Washington as a representative of the British Hydrological Section of the International Union of Geodesy, Mr. McClean had been conducted individually through the Water Survey section of the Bureau of Standards and was shown much of the apparatus used, including a tank for the rating of current-meters. At the National Physical Laboratory current-meters could not be tested for low velocities, and that had been a serious handicap to flow-gauging work.

The maintenance of continuous and reliable records was an absolute necessity, but it was no easy matter. It required local organization, as with rain-fall records; but it should not be operated on a voluntary system. An independent hydrographer should be in charge of a County or Catchment-Board area, and the data and records should be stored locally. That was a primary step in the correct decentralization of records. The hydrographer should not be the servant of a Catchment Board, whose interests were frequently antagonistic; and the finance should be met by the State and not by the Catchment Board or the County.

Those suggestions were made on the basis of Mr. McClean's wide experience in carrying out the measurements and maintaining the records on the five largest rivers of the Ness and Lochy basins of the Great Glen; on two widely separated sites on the river Spey; at the principal station on the Aberdeenshire Dee; on the river Leven out of Windermere; and on the Chester Dee.

The practical work was commenced in 1912, but was interrupted by the war of 1914-1918. Since 1929 it had proceeded continuously and until the outbreak of the present war. The records were being carried on, although the Inland Water Survey Committee of the Ministry of Health had ceased to function after 2 years. That Committee had done very valuable work, and many new records had been added; but it had been entirely dependent upon the Catchment Boards.

Inland Water Survey required an executive department of its own, as with land and marine survey. The record-keeping was a matter for local organization under that department's guidance, whilst the finance was a matter for the State.

A feeling existed that the Department of Scientific and Industrial Research should control the survey; Mr. McClean's opinion was that that Department should ensure the scientific development of the survey in the work at the National Physical Laboratory.

Mr. T. H. Turner, of Doncaster, observed that he found the "Water Pollution Research Summary of Current Literature" of considerable value but he would welcome the completion of an Inland Water Survey. In that

connexion the various railway laboratories could supply analyses of many hundreds of locomotive feed-waters and drinking waters. So far as he was aware, no request had ever been made to the Railway Companies to supply such analyses. If that were done, a point which would immediately arise was the need for standardization of at least two report forms, one for boiler feed-waters and the other for drinking water. That was, he suggested, a matter for the British Standards Institution Chemical Section. Public analysts, railway chemists, and others could be furnished with such forms by the central organization of the Inland Water Survey, and asked to complete them with as many details as possible whenever future analyses were made. That would entail a little trouble, but would result in a considerable service to the public.

It had been noticed that when locomotive feed-water had been softened, the algae which previously grew in the pick-up troughs on the London and North Eastern Railway had been eliminated, but the alkalinity maintained (pH value of 9 or more) was higher than that of domestic water-supplies. He considered that the treatment of water to prevent corrosion should become the rule: at present it was the exception. Large installations of water softeners should be encouraged, even at the present time, in order to save soap. He believed the Germans had made a drive in that direction before the war.

The Author's reference to the lime/soda process had made no mention of the addition of sodium aluminate. Mr. Turner attributed the success of his locomotive feed-water treatment largely to the addition of sodium aluminate, which had permitted the almost complete softening of really bad waters containing magnesium, which previously had remained corrosive when softened down to $8-10^{\circ}$ Clark: attempts to soften below that value, without sodium aluminate, had resulted in after-precipitation.

Zeolite softening was very convenient for hotels and laundries, but on the London and North Eastern Railway difficulty had arisen from the corrosion of pipe-lines for the hot-water service. The by-passing of some unsoftened water appeared to be necessary. Since corrosive activity was, in accordance with normal chemical experience, increased in proportion to the increase in temperature, it was natural that trouble should arise in the hot water supplies. As a rule, however, there was little need to soften the cold water.

Some trouble had been caused through corrosion of hydraulic mains, and an addition of sodium silicate had been found to be helpful. A study of the corrosion of hydraulic mains would seem to be a matter of interest to The Institution. The Americans were making considerable experiments with the Langelier index, which was obtained by comparing the pH value of the fresh water with that of the same water after saturation with lime. Sufficient evidence was not yet available to show whether that index could be of real value.

Mr. R. C. S. Walters considered that engineers, and certainly water

works engineers, should become more and more aware of the need of a comprehensive survey of water resources, and of the work of the Inland Water Survey Committee, the Geological Survey, the Water Pollution Research Board, the British Association, the British Rainfall Organization, and the Freshwater Biological Association.

It was only the engineer who assimilated such knowledge, and who, after the war, could prevent such absurdities as (1) the establishment of electric power-stations dependent for cooling water upon a stream 90 per cent. of whose flow was a sewage-works effluent; (2) the ruination of underground supplies by discharge of colliery water from deep sources containing much calcium chloride and/or sodium carbonate on the surface; (3) such statements as, "Our chemist says there are 5.0 parts of chlorine in the water, and, therefore, as it contains so much residual chlorine, it need not be treated" (*sic*!); to mention only three instances in Mr. Walters' experience.

The Paper was thoroughly practical, and many of the wise saws and modern instances quoted were within his own experience, including the importance of the pH value, algal growths, and water weeds. The latter were difficult and expensive to eliminate, but the chief rough and ready remedy was frequent use of the scour-pipe.

In practice only the quantities of wash-water and chemicals were available to furnish any comparison between one process of filtration and another, but unfortunately those were based upon waters in different parts of the country, which varied seasonally. Some large-scale experiments of different processes side by side were definitely desirable.

Engineers should be guided in their choice of a softening method by full analyses of the water: some waters softened by the base exchange method resulted in a weak supply of Epsom and Glauber salts, which was doubtless one of the inconveniences alluded to by the Author on p. 378 *ante*. The difficulty of disposing of the precipitated sludge in the lime process should not be over-emphasized, for in some instances that sludge had a fair market value and could be sold.

The importance of fluorine (brought about by the increase in the chlorination of the nation's water-supplies in recent years) would be new to many, including analysts and medical officers. It would be valuable if some body like the British Standards Institution could publish a list of the substances in water which the analyst had to examine, in order to strengthen the hand of many "lay" engineers with the analytical advisers of the authorities for whom they acted.

Mr. J. Noel Wood observed that the Author's figures for the quantities of water available and required were, no doubt, the result of careful research; but he wondered whether 20-25 gallons per person per day for domestic purposes was really the average domestic consumption for Great Britain. That average might be accurate for England, but had the Author taken into account the enormous quantities supplied for that purpose in

Scotland, where domestic consumptions of double that quantity were common?

Mr. Wood heartily supported the Author's hope that after the war the work of the Inland Water Survey work would not only be restarted but also extended. The difficulties in the way of obtaining a reliable assessment of national underground sources of water-supply were, if not insuperable, at least enormous. Overground sources, however, could and should be assessed much more readily; but no great headway would be made until the furnishing of stream-flow records from existing gauges became obligatory. Examination of the three Annual Reports already published by the Inland Water Survey showed that only the more progressive authorities had voluntarily been prepared to have their records "vetted" and published. In spite of the obvious advantages to any undertaking to have its run-off figures examined critically by an independent authority, the vast majority still held back, although they willingly allowed their rainfall data to be checked and published. All water engineers knew that whilst rainfall returns were valuable, it was the run-off and not the rainfall which was counted upon to fill the reservoirs.

Apart from the advantage of having an "outside" check—not only of the records, but also of the recording instruments and stream-gauges—there was a tremendous value in having Government-approved run-off values which would be acceptable to all sides in Parliamentary Bills, arbitrations or lawsuits. But Mr. Wood feared that until the Inland Water Survey Committee was armed with compulsory powers there could never be any such comprehensive survey as that envisaged by the Author. Moreover, even if such powers were to be conferred, it was unlikely that the survey could be quickly expanded and established long enough for any records of much value to be ready for use in the immediate post-war planning.

With the marked advance in water-treatment technique, possibly a feeling had developed that the need for care against pollution of a supply at source had disappeared. The price of providing a pure and wholesome supply was endless vigilance at all stages. With the development of rural areas and the intensification of the "hiking" vogue, with its no doubt admirable desire for more and easier access to mountains, there was an increasing danger of pollution of supplies, even from gathering-grounds which had hitherto been regarded as inviolate. The Author had very appropriately referred to that subject in his remarks on Disinfection or Sterilization. Sterilization should, indeed, be regarded only as a final insurance against possible breakdown of previous treatments.

The treatment of plumbo-solvent waters by passing them over beds of limestone chippings had long been considered unsatisfactory, but in remote areas where constant control could not be provided the method had been largely adopted because of its simplicity. Mr. Wood, who had had the opportunity of seeing the experimental work referred to by the Author on

p. 384, *ante*, thought that by the very nature of things the limestone chipings method could never prove a success. He considered that the problem was essentially a mechanical one, and that research might be more usefully directed to devising some simple foolproof contrivance for the addition of lime or other suitable alkali.

The Author, in reply, observed that before giving figures for the quantities of water available and required in Great Britain he had reviewed the best available data, and he believed that as a result the estimates were reliable. He agreed with Mr. Wood that in many parts of Scotland the quantity of water used for domestic purposes was much greater than 25 gallons per person per day. There were also many areas in England with relatively high consumption of water for domestic purposes. At the same time there were many areas in which the quantity was less than 20 gallons per person per day. Allowing for those differences, and for the much smaller population of Scotland in comparison with England, he had concluded that 20–25 gallons per person per day was a fair overall average of domestic requirements. That estimate was not intended as an average of the quantity of water distributed by water-supply undertakings per person per day, as a proportion of the water distributed by such undertakings was used for industrial purposes.

All correspondents had agreed on the need for a comprehensive survey of the water resources of Great Britain. The views of Mr. McClean, who over many years had done much valuable work in surveying rivers and lakes, were interesting. In a complete survey, including data on the composition of various waters, the Railway Companies could, no doubt, give considerable assistance, as Mr. Turner had suggested, in providing the results of analysis of many waters. Local authorities and other organizations and individuals could probably also assist in the same way. It was desirable, as Mr. Turner and Mr. Walters had pointed out, that some definite lead should be given in standardizing methods of water analysis and of presentation of the analytical results, so that analytical data could be properly compared and interpreted. The position in Great Britain at the present time was certainly not entirely satisfactory in that respect. The Author realized that there were organizations which had not been willing to supply the data they had obtained on certain surface and underground water resources, because of the risk of encouraging others to enter into competition in drawing on those resources. He did not believe, however, that the difficulty in persuading the vast majority of those who had useful data to send the information to a central office for correlation was so great as had been suggested by Mr. Wood.

It was interesting to know from Mr. Turner that when locomotive-feed water had been softened, algal growths had no longer developed in the pick-up troughs on the railway track. It might have been, as suggested, that algae would not grow so readily when the pH value of the water had been raised. There was the probability, however, that during the soften-

ing, the organic matter and other substances which served as nutrients for algae had been removed or reduced in quantity, particularly when treatment included the addition of a softening and flocculating reagent such as sodium aluminate. With many waters complete softening by the zeolite process increased the corrosive action of the water on metals, especially when the water was heated, because the process did not remove free carbon dioxide and the completely softened water did not form a good protective coating on the metal. In such instances, with zeolite softening, it was often advantageous to mix a proportion of hard water with the water leaving the softener, or periodically to supply the system with unsoftened water for one or two days. Reference had been made to the "Langelier index", as used to some extent in the United States of America, as a measure of the probable relative corrosive character of waters. A similar test, in which the sample of water was shaken with powdered calcium carbonate, had been used frequently in investigations made by the Water Pollution Research Board. In those investigations, the changes in the pH value and alkalinity of the water on shaking with calcium carbonate and filtering had been correlated with the changes in the quantity of lead taken up by the water when allowed to remain in lead pipes.

The Author agreed with Mr. Jackson that in certain circumstances the new process of removal of salts from water by treatment with base-exchange and acid-exchange materials possessed advantages over the method of evaporation and condensation. In that new process, which was based on discoveries made in experiments carried out in 1934 and 1935 at the Chemical Research Laboratory at Teddington for the Water Pollution Research Board, the base-exchange material required periodic regeneration with a solution of acid and the acid-exchange resin required regeneration with a solution of alkali. Unless solutions of acids, such as sulphuric acid, were used under supervision, considerable damage could be caused. The Author did not agree, therefore, that the process could be properly operated by unskilled labour.

ORDINARY MEETING.

23 June, 1942.

Professor CHARLES EDWARD INGLIS, O.B.E., M.A., LL.D.,
F.R.S., President, in the Chair.

The Council reported that they had recently transferred to the class of

Members.

ERNEST BATESON.	ALAN PERCIVAL LAMBERT, B.Sc. (Eng.)
WILLIAM FILLINGHAM BROWN, B.Sc.	(Lond.).
(Eng.) (Lond.).	JAMES DRYSDALE MALCOLM,
ALFRED GEORGE BUGDEN, B.Sc. (Eng.)	JOHN RONALD MALCOLM, B.Sc. (Eng.)
(Lond.).	(Lond.).
FREDERICK JONATHAN BYWATER, M.C.	RAYMOND BURROWS PORTEB, B.Sc.
ARTHUR FLOYD, B.Sc. (Durham).	(Edin.).
FREDERIC ARTHUR HARPER, M.A. (Can-	RALPH HENRY QUINTON, B.Sc. (Eng.)
tab.).	(Lond.).
THOMAS EVANS HOUGHTON, M.Eng.	ROBERT GEORGE SMITH, B.Sc. (Edin.).
(Liverpool).	BERNARD WHITTERON.

And had admitted as

Students.

REEVEL ALDERSON.	JAMES ALEXANDER TORRANCE PAIRMAN.
DONALD WILLIAM BARCLAY.	CHANDRASEGARAMPILLAI PASKARANAN-
ALFRED EDGAR BURROUGHS.	DAVEL.
JAMES CARROLL.	CECIL MARCEL PERERA, B.Sc. (Eng.)
KENNETH JAMES COLE.	(Lond.).
HILARY MICHAEL DALE.	JAMES HOWARD PONTEFRACT.
MICHAEL JOHN DAVIS.	DENNIS COLLEY REDFERN, B.Sc. (Man-
HENRY DUCKWORTH.	chester).
GEORGE ROBERTS HALL, B.Sc. (Man-	KEITH ROBSON.
chester).	HENRY EVAN BERNARD SIMS.
ROBERT MARTIN HOLLOWAY.	RICHARD PETER SLEEP.
JOHN ELWYN JAMES.	MARCUS ALLAN STONEBRIDGE.
LESLIE JOHNSON.	PHILIP ROGER STRATTON.
GEORGE MORIAN JONES.	VICTOR JOHN RONALD SUTTON.
STANLEY JONES.	CLIFFORD LINDSAY WATT, B.Sc. (Man-
SLADKUS HANUS KAREL.	chester).
BRIAN JOHN BARNETT LISTER.	DON ROBERT WEERASIRIE.
GORDON STANLEY LUCAS.	RONALD LESLIE WHITE, B.Sc. (Eng.)
ALEXANDER McLAREN, B.Sc. (St. An-	(Lond.).
drews).	COLIN WILLIAMS, B.Sc. (Manchester).
PHILIP HUGH MARSHALL.	JOHN STAFFORD WOOD.
WILLIAM JOHN EDWARD MILES.	MOSTYN JOHN WOOD.

The Scrutineers reported that the following had been duly elected as

Associate Members.

MAURICE OWEN KINLOCH ANSTISS.	WILLIAM HENRY NEWMAN.
JOHN STANLEY BERRY, B.Sc. (Eng.)	PATRICK O'CONNELL, B.E. (<i>National</i>).
(<i>Lond.</i>), Stud. Inst. C.E.	PAUL CHARLES PEPIETTE, B.Sc. (<i>Birm-</i>
WILLIAM FERRIER BROWN, Stud. Inst.	<i>ingham</i>), Stud. Inst. C.E.
C.E.	JOHN GARNET PERRY, B.E. (<i>New Zea-</i>
JOHN WRATHALL CHARNLEY, Stud. Inst.	<i>land</i>).
C.E.	FRANK SHEARBURN PILDITCH, B.Sc.
STANLEY RUSSELL CLARKE, B.E.	(<i>Edinburgh</i>), Stud. Inst. C. E.
(<i>National</i>), Stud. Inst. C.E.	HAROLD VICTOR ROUNTREE, B.Sc. (Eng.)
ERIC ARTHUR DONOVAN.	(<i>Lond.</i>).
ROBERT CHARLES FORBES, B.Sc. (<i>Wit-</i>	WILLIAM REGINALD SHEPHERD.
<i>watersand</i>), Stud. Inst. C.E.	THOMAS FREDERICK WYATT SMITH, B.Sc.
GAURCHANDRA GHOSH, B.E. (<i>Calcutta</i>).	(Eng.) (<i>Lond.</i>), Stud. Inst. C.E.
WILLIAM HUNTER GRANT.	MORTON ALEXANDER THOMAS.
NICHOLAS GEORGE HALABY.	LEWIS HAMILTON THOMASS, B.E., B.Sc.
HAROLD HARTLEY, B.Sc. (<i>Leeds</i>).	(<i>New Zealand</i>).
NERIEL JACOBSON, B.Sc. (<i>Cape Town</i>).	JERZY GEORGE THON, M.Sc. (Eng.)
HAROLD KENNEY, M.A. (<i>Cantab.</i>).	(<i>Lond.</i>).
ROYLYN MUIR MCCALLUM, B.A. (<i>Punjab</i>).	ARTHUR SELWYN IVATT TIFFIN.
STEWART MCGREGOR.	JOHN WAREING.
ERNEST HENRY MACMILLEN, B.Sc. (<i>Man-</i>	LEIGHTON MELSON WINGATE, B.Sc.
<i>chester</i>).	(Eng.) (<i>Lond.</i>).

ANNUAL GENERAL MEETING.

23 June, 1942.

Professor CHARLES EDWARD INGLIS, O.B.E., M.A.,
LL.D., F.R.S., President, in the Chair.

The President, presenting the Report of the Council for 1940-41, as published in the June 1942 number of the Institution Journal, observed that following the custom of recent years, he would assume that members were already acquainted with its contents. He would therefore concentrate his attention upon some of its more salient features and add a few observations on other activities of The Institution which were in process of evolution.

The first page of the Report (p. 337 *ante*) recorded the meetings which had been held during the session. A notable feature had been a number of conferences in co-operation with other engineering institutions. He thought he might say that those joint meetings had been a pronounced success. Those on Air Raid Precaution measures and on statistical methods of achieving quality control had attracted very large audiences, numbering a thousand and even more in the first case. The tendency

towards a greater solidarity among engineering institutions had in that and other ways made substantial progress, and it was now becoming recognized with increasing clarity that, in order to raise the status and enhance the prestige of the engineering profession, everything possible should be done to close the ranks and achieve that strength and authority which unity alone could provide. With that object in view the Presidents and Secretaries of the major institutions were meeting frequently to discuss informally matters of common interest, and in that way the ground was being prepared for the cultivation of many possible schemes of helpful co-operation. As an example of what had already been done, a Joint Preliminary Examination was now in operation, and the possibility of a joint examination to cover certain fundamental parts of the Associate Membership Examination was being considered by the Institutions of Civil, Mechanical, and Electrical Engineers.

It would be noted, from p. 338 *ante*, that the Road and Railway Engineering Sections had shown considerable activity, and without doubt those Sections were contributing an added vitality to The Institution and opening up enhanced opportunities of service to the profession. It was hoped that in the near future other Sections would be formed. To signify their growing importance, it was intended that in the future they should be called "Divisions" and should be controlled by Divisional Executive Boards, on which the Local Associations might very suitably be represented. That was one way whereby the excellent work of the Local Associations could be more closely identified with that of the central organization; and that close co-operation was an ideal most earnestly desired both by the Council and by the Local Associations.

The Council had noted with satisfaction that, in spite of wartime conditions, the Local Associations had been able to increase their activities during the past session. In particular, the Edinburgh and the Yorkshire Associations had carried out a full programme of meetings with all their pre-war vigour; and, as a result of a recent visit to a meeting at Sheffield, he could testify at first hand his appreciation of the hospitality and enthusiasm of the Yorkshire Local Association.

Reference had been made, on p. 340, to the course of lectures on Engineering Economics, Management and Aesthetics which The Institution has endowed at Cambridge University, and in that case also he could declare with first-hand knowledge that those lectures had been an unqualified success and had fulfilled a very useful purpose. Although attendance was voluntary and the lectures were delivered in the evening "black-out" the audience on many occasions exceeded 300. In the future those lectures would be incorporated as a regular part of the educational curriculum of the Cambridge Engineering Department, and, as such, they would take place in the day-time.

The response on the part of senior members of The Institution to the request that they should give lectures to student engineering societies had

been very gratifying. Many such lectures had been delivered, and the Council sincerely appreciated the public-spirited way in which their appeal for such assistance to the cause of engineering education had been received.

On p. 341 the Report dealt with the activities of the Committee on Post-War National Development, under the chairmanship of Sir Clement Hindley. Some of the problems dealt with therein had introduced an element of politics, concerning which unanimity among members of The Institution could hardly be expected or achieved. In particular, some of the views expressed by the Committee in its report on the Barlow Commission dealing with the Distribution of the Industrial Population had been challenged in several quarters, and a deputation from the Institution of Municipal and County Engineers had been received, with whom certain objections to statements in the report were discussed in a helpful and conciliatory manner. As a result, amendments had been embodied in the report, and it was hoped that in the revised edition a general agreement had been achieved.

Engineering education was now attracting widespread interest, and a special Committee set up by the Council had prepared a Report on the past and future education and training of civil engineers. That Report contained material some of which, no doubt, would be regarded as controversial and, profiting by the experience recently gained, it would be circulated for comments before being issued as a document having the authority of the Council, and would possibly be the subject of a discussion at an Ordinary or a Supplementary Meeting of The Institution.

Recently the Council had protested vigorously against a memorandum issued by the Technical Personnel Committee presided over by Lord Hankey, which prescribed that in future deferment from the calling-up of university engineering students would be granted only to those who were studying mechanical or electrical engineering. Civil engineering students were not to be accorded deferment, and that would have meant that in the future, at all events for the period of the war, no recruits for the civil engineering profession would be forthcoming from any university civil engineering department. As the result of the Council's protest, backed up by other engineering institutions and by the universities, an appendix to the memorandum had since been issued stating that students in the civil engineering departments of the universities would be given deferment provided that those departments introduced into their courses a sufficiency of instruction in mechanical and electrical engineering. In view of the present heavy demands by the fighting forces for mechanical and electrical engineers, that formed a reasonable solution of the immediate problem of supply and was, in effect, the actual solution recommended by the Council.

On pp. 342 and 343 information was given relating to the number of Members, Associate Members, and Students serving with the armed forces; as might be expected, the majority were serving as commissioned officers in the Corps of Royal Engineers. The problem of how those who were

still in the student stage could be helped towards passing the examination for Associate Membership was constantly under consideration by the Education and Training Committee. To meet the needs of prisoners of war in Germany, facilities were being provided, with the assistance of the British Red Cross Society, whereby they could study for and take the Institution examinations in their respective camps.

So far as the qualifications for corporate membership were concerned the Council were firm in their resolve that no lowering of the general standard of election could be permitted. The only wartime concession they could make were that men in the services, who had limited opportunities for study, could take the examination subjects two at a time, and that civilian students who failed in one particular subject were generally required only to make good that deficiency, instead of taking the whole examination again.

The Council had under consideration a comprehensive re-casting of Examination B. In the future the subjects would be arranged in nine groups, and candidates would have to confine their attention to one group only. In whichever group he selected, a candidate would be examined in five subjects instead of three, as formerly, four of them being compulsory and the fifth being selected from a choice of alternatives. In the new form of the examination, a wider and certainly a better balanced range of knowledge would be required, and the examination, thus modernized, would be brought into step with engineering progress.

Two of the groups dealt with Building Engineering and Construction Engineering, and those would cover the lighter and heavier types of engineering construction respectively. In those subjects the teaching facilities provided throughout the country were at present very inadequate, and a movement had been initiated whereby The Institution might co-operate with the Board of Education in bringing into existence National Certificates dealing with constructional engineering.

Civil engineering depended for its success largely upon the competence of its responsible non-commissioned officers, such as senior draughtsmen, clerks of works, and inspectors. At present that talent was lacking in co-ordination; it possessed no recognized official status and the knowledge of fundamental principles which it acquired had, in general, to be self-taught. The Council had been considering seriously how The Institution could help that large class of engineers who, invaluable as they were to the profession, could seldom aspire to corporate membership. It might be helpful to form a new class of non-corporate associates; or, alternatively, there was the possibility of conferring on that non-commissioned class some official status by means of a diploma or certificate given on the results of a suitable examination in theoretical principles combined with satisfactory evidence of practical competence in a position of responsibility. Towards that end the establishment of National Certificates in construction engineering would give a powerful stimulus. It would provide alternative

to the examinations that The Institution might organize, and it might stimulate the technical schools to devote more attention to the educational needs of the constructional engineer.

Concerning research, it was a matter of regret that wartime conditions had, of necessity, considerably curtailed The Institution's activities of that character. Research called for certain leisure of mind and opportunities for peaceful introspection which were not attainable at present, and although doubtless many members of The Institution were actively employed on engineering research, such work was of a secret nature and not of a character which could be the subject of an Institution Research Committee.

The Accounts for the year, summarized on p. 344, showed that The Institution was in a satisfactory condition of solvency, as was indicated by the fact that the final credit balance was £3,500, whilst the cash at bankers and in hand at the close of the financial year amounted to £20,806, as compared with £17,567 at the same period last year. One of the heaviest items of expenditure was the Publications Account. For that an allocation of £11,000 had been provided, and it was satisfactory to note that the expenditure had been £1,835 less, so that at last that account could show a credit balance to be carried forward. It was very desirable that that account should build up a substantial credit reserve available for the time when certain Papers now held up would be released for publication. The importance of maintaining and enhancing the excellence of the Journal could hardly be overestimated. The Council believed that, in spite of the paper shortage and the ban of secrecy imposed by the Censor, that had been done; and evidence that such was the case was forthcoming from the sales, which during the past year had shown a gratifying upward trend.

On p. 347 charts were given, setting forth the numbers of corporate members and Students on the roll of The Institution during the past 37 years. Although for the past 20 years the numbers of Associate Members and Students had shown a steady increase, it was remarkable that the number of full Members had remained almost absolutely constant. The curves comprising the lower series of charts, although perhaps a little difficult to follow, supplied valuable information, particularly regarding the admission of Students and those who proceeded no farther. There was no doubt that many Students, after they had become actively engaged in practical engineering, tended to procrastinate in regard to the Associate Membership examination, and the longer they did so the more formidable that obstacle became. It was hoped that that regrettable tendency would be recognized by employers, and that pressure would be applied to induce Students to take the Associate Membership examination at the earliest possible date, and that facilities for preparing for that examination would be afforded, even if the students' other activities and immediate usefulness were curtailed thereby.

In conclusion, he would like to pay his tribute to the loyalty and

efficient work of The Institution staff, under the leadership of their most competent and courteous Secretary, Mr. Graham Clark. He had often heard eulogies on that subject from Presidents in the past, but until his turn came he had not fully realized how much The Institution owed to those who worked unobtrusively behind the scenes. Difficulties which might have been anticipated owing to shortness of staff had in all cases been overcome by extra effort, and the whole organization worked so smoothly that one was hardly conscious of the machinery which kept it in motion. But because that good work was unobtrusive it should not be taken for granted, and he was sure that not only the members of the Council but also The Institution as a whole would join with him in recognizing their debt of gratitude to all the members of the permanent staff for their hard work, their efficiency, and their loyal devotion to The Institution.

Mr. J. S. Wilson observed that the curves showing the membership of The Institution during the past 37 years were very illuminating, and he hoped that the Council were considering the extraordinary state of affairs which was so clearly indicated, namely, that whilst the number of Associate Members was steadily increasing, the number of Members had remained at an almost dead level. In 1905-06, for instance, the number of Members was about 2,300, and in 1941-42 it was practically the same, whereas between 1905-06 and 1941-42 the number of Associate Members had increased from 4,200 to 7,800, or about 86 per cent. Doubtless the standard of requirements so far as the Associate Members were concerned had risen in that period, but either the standard demanded as to character and training, and so forth, of the full Member had increased very much more or something else had happened.

If the number of 2,300 full Members had increased by 86 per cent. their total should now stand at 4,270—an increase of nearly 2,000. Two thousand transfers to membership at 12 guineas each was worth thinking about!

He considered that the chart was a very valuable one, and it reminded him of something that he had done about 35 years ago, when he had been very annoyed with the Council because they had cut down the diagrams in a Paper for which he was partly responsible, and had committed other cheese-paring acts in connexion with that Paper. He had then prepared several diagrams showing the expenditure on publications, and on junketings and so forth, over a number of years, and had shown that the expenditure on publications had been decreasing whereas the expenditure on the other matters had been increasing.

The statistical graph method was, he thought, very valuable, and he would like to congratulate the Council on having introduced it. He suggested that in future Reports a similar kind of record should be included covering a period something like that covered by the graph in the present Report.

Mr. P. J. H. Unna said that the Report showed that a great deal of

thought was being given to planning for post-war reconstruction. In the past, engineers' plans had occasionally—perhaps often—been defeated on amenity grounds by people who were merely busybodies. He thought that if there were earlier co-operation between engineers and the people concerned with amenities, who were growing very strong and would grow much stronger in the future, so that agreement could be reached and schemes formulated in a way pleasing to all concerned, great benefit to the country would ensue. He had in mind such bodies as the Amenities Group in the House of Lords and the House of Commons, which was a very powerful body, having meetings with an attendance of sometimes 300 members, and also such organizations as the Society for the Preservation of Rural England, the Society for the Preservation of Rural Scotland, and the non-fighting societies, like the two National Trusts.

Mr. A. T. Best said that reference had been made in the Report to "the high standard of the discussions" at the meetings of The Institution. Without for a moment differing from the view that the contributions reached a high standard, he questioned whether the word "discussions" was quite the right one to use. Members knew how common it was becoming for a series of supplementary Papers to be read at the meetings; and although they constituted a very valuable contribution to the Journal, he submitted that they tended to reduce the human interest of a meeting at which discussion was supposed to be taking place. He suggested that the Council should more rigorously enforce the existing rule that prohibited the reading of contributions, though not the use of notes. At the present time that rule seemed to be more honoured in the breach than in the observance. If such reading were restricted, more time would be available for discussion properly so-called, in the nature of free debate, and that would add greatly to the interest of the meetings.

Another point was that by reason of the number of supplementary Papers that were read, frequently no time was left at the end of the meeting for the Author's reply, whereas he was sure that it would be more interesting to members if the Author could reply there and then to the points raised in the discussion, rather than that his reply should appear in the Journal some weeks or months later.

The interesting graph to which reference had already been made was of peculiar interest to him, because it happened, within one year, to coincide with the period of his own corporate membership of The Institution. He wished to refer to a point that had already been mentioned, namely, the extraordinary growth of the Associate Membership. Whereas 37 years ago there had been twice as many Associate Members as full Members, there were now four times as many; yet the Associate Members were not represented on the Council. There was nothing in the By-laws to exclude them; it was open to members, in principle and in theory, freely to elect them to the Council, but in practice it was utterly impossible for anyone to become a member of the Council unless his name appeared on the balloting

list issued by the Council. That raised indirectly another point, affecting the representative character of the Council.

The President, interposing, reminded Mr. Best that it had been ruled at the last Annual General Meeting that it was not in order to discuss the question that he was now raising. Mr. Best could discuss any matter that was dealt with in the Report of the Council, but it was really outside the business of the meeting to deal with a reform or modification of the method of electing the Council.

Mr. A. T. Best, in conclusion, said that the Annual General Meeting gave the members their one opportunity, which they very much prized, of raising such points.

The President said that Mr. Best could give notice of his intention to bring forward a motion on the subject.

Mr. R. Chalmers said that the Report contained a record to which the President's address had made some notable additions, of recent events on which the Meeting might well offer its congratulations and thanks to the Council, particularly in respect of the series of Lectures and Papers, which he thought had broadened the members' conception of the species of knowledge which constituted the profession of civil engineer. Sometimes The Institution seemed to be devoted to the interests of the profession. For example, the Memorandum last year to the Expert Committee on Compensation and Betterment had staked a large claim for the engineering profession in matters of town and country planning, and the evidence which The Institution furnished some years ago to a Government Departmental Committee on Local Government Officers even advocated satisfactory standards of remuneration. Unfortunately there were contrary instances. The point he wished to make was that where The Institution had promoted the interests of the profession it had also served the public interest. He was unable to conceive a position in which those interests would conflict, and it therefore seemed to him to be the duty of the profession to promote its own interests, if only for the reason that by so doing it would serve the public interest. The only real question was whether that was to be done by means of the Institutions or by some other agency, and he suggested that there was good reason why it should be done through the Institutions. The matter was urgent and the Institutions were increasing, with great potential strength by virtue of their large membership, and their adaptation for the purpose would be more speedy than the development of an alternative organization.

He suggested that amongst the Divisions of which the President had spoken, there might be one, analogous to the Road and Railway Engineering sections, having as its subject matter the social responsibilities of the engineering profession. If such a Division or section could work in co-operation with similar sections of the Institutions of Mechanical and Electrical Engineers, he thought that a body of engineering opinion would be formed on that subject that would come to have great public value.

The President, in reply to the comments made on the Report, said Mr. Wilson had drawn attention to the remarkable fact that the number of full Members remained constant whilst the number of Associate Members increased, and had spoken of the financial gain which would accrue to The Institution if a reasonable proportion of the Associate Members became full Members. Perhaps that was what stood in the way of their doing so. He felt that there must be some cause of that sort, and perhaps it would be better to charge Associate Members rather more and full Members rather less, so that the passage from Associate Membership to full Membership would be comparatively painless! He remembered that in his own university there used to be a difficulty in inducing B.A.'s to become M.A.'s, but when the fee for the B.A. was increased to such an extent that a man had to pay only about another £1 to become an M.A. nearly all the B.A.'s became M.A.'s. Perhaps that was an indication of the way in which The Institution should grapple with the problem.

Mr. Unna had pleaded for greater co-operation with amenities groups, and that was a constructive suggestion to which importance ought to be attached. He thought the Council could say that they were making moves in that direction and were endeavouring to make the weight of The Institution felt to a considerably greater extent than had been the case in the past.

Mr. Best had drawn attention—he thought quite rightly—to the fact that in the discussion of Papers there was a good deal of breaking of the rule that members must not read their remarks, and perhaps as President he had been remiss in not calling to order the members who broke that rule; but he had only been following the lead of many previous Presidents, and he was afraid it had become the custom to condone that particular offence. Whether it should continue to be condoned was another matter. He believed that members of The Institution were not the only offenders, as he understood that in Parliament to-day about nine out of ten speeches were read, and that would not have been allowed in the old days. He was glad that Mr. Best had drawn attention to the subject, because his remarks positively indicated a general feeling on the subject.

It was difficult to reply to Mr. Chalmers, who evidently thought that all was not well with The Institution. He could assure Mr. Chalmers that the Council did not feel any complacency about the work that they were doing. It might perhaps sound feeble to say so, but they were doing their best and were endeavouring to keep thoroughly in tune with all developments and to promote the interests of the members so far as they were permitted to do so. They could not act as an appointments body. A body had been set up by the Government to do that—the Central Register—and the Council could not encroach upon the activities of the Central Register even if they were permitted under the Charter to do so, and that was not the case.

He found it difficult to grasp the exact grievances that Mr. Chalmers had expressed, but after he had had an opportunity of reading what Mr.

Chalmers had said he would probably find some definite clear-cut items which could be considered with a view to rectification.

The President then moved that the Report of the Council be received and approved.

Mr. R. Carpmael seconded the motion, which was agreed to by the members present.

The Scrutineers reported the election of the Council for 1942-43 as follows¹ :—

President.

Sir JOHN EDWARD THORNYCROFT, K.B.E.

Vice-Presidents.

David Anderson, LL.D., B.Sc.	Sir Thomas Pierson Frank.
Francis Ernest Wentworth-Sheilds,	Asa Binns.

Other Members of Council.

Wilfrid Philip Shepherd-Barron, M.C., T.D.	Gerald Lacey, C.I.E., B.Sc. (<i>India</i>).
Raymond Carpmael, O.B.E.	Malcolm Gordon John McHaffie.
Sir Harold Nugent Colam, B.A. (<i>India</i>).	Charles Matthew Norrie, D.S.O., B.Sc.
Sir Frederick Charles Cook, C.B., D.S.O., M.C.	Sir Standen Leonard Pearce, C.B.E., D.Sc.
Professor Gilbert Cook, D.Sc., F.R.S.	Allan Stephen Quartermaine, M.C., B.Sc.
Henry Francis Cronin, M.C., B.Sc.	Vernon Alec Murray Robertson M.C.
Sir Jonathan Roberts Davidson, C.M.G., M.Sc.	Professor Alfred Ernest Snape M.Sc. (<i>S. Africa</i>).
Richard John Durley, M.B.E., B.Sc. Ma.E. (<i>Canada</i>).	Reginald Edward Stradling, C.B., M.C., D.Sc., Ph.D.
William Henry Glanville, D.Sc., Ph.D.	Alec George Vaughan-Lee.
Harold John Frederick Gourley, M.Eng.	James Vicars, M.E. (<i>Australia</i>).
William Thomson Halcrow.	David Mowat Watson, B.Sc.
Herbert Hamer.	Herbert Cecil Whitehead.
Robert John Mathison Inglis, T.D.	John Wood, C.M.G. (<i>New Zealand</i>).

Mr. R. Chalmers proposed—That the thanks of the Meeting be given to the Scrutineers and that the ballot papers be destroyed.

Mr. A. T. Best seconded the motion, which was carried unanimously.

Mr. A. S. Grunspan, responding on behalf of the Scrutineers, thanked

¹ The Council commence their term of office on the first Tuesday in November 1942.

the Meeting for the resolution. The tradition of The Institution, he said, was a heritage of which the members might be justly proud, and he thought he was expressing the opinion of all the members when he said that they were very anxious to perform a service of one kind or another for The Institution. It was no wonder, therefore, that the Scrutineers carried out their task, albeit a small one, with great alacrity. They served The Institution to-day as Scrutineers, and they hoped to serve it in some greater capacity to-morrow.

Mr. J. S. Wilson moved—That Mr. J. D. C. Couper, Member, be reappointed Honorary Auditor for the current financial year, and that Sir Alan Rae Smith, O.B.E., be reappointed professional auditor.

Mr. B. F. Browne seconded the motion, which was carried unanimously.

The following Awards made by the Council during the past year were announced :—

A Webb Prize to :—

J. D. Watson, B.Sc. (Eng.), Assoc. M. Inst. C.E., joint Author of Paper “Hammer-Blow in Locomotives: can it not be abolished altogether?”

Telford Premiums to :—

L. F. Cooling, M.Sc., for his Paper on “Soil Mechanics and Site Exploration.”

Albert Parker, D.Sc., for his Paper, “Treatment of Water for Domestic and Industrial Requirements—Some Problems and Methods.”

H. J. B. Manzoni, C.B.E., M. Inst. C.E., for his Paper, “Post-War Planning and Reconstruction.”

A. H. D. Markwick, M.Sc., Assoc. M. Inst. C.E., for his Paper, “Soil Mechanics in Road and Aerodrome Construction.”

Norman Davey, B.Sc. (Eng.), Ph.D., M. Inst. C.E., for his Paper, “The Surface Finishing of Concrete Structures.”

For a Student's Paper read at a Meeting of a Local Association.

A Miller Prize to :—

M. C. Privett, Stud. Inst. C.E., for his Paper, “Modern Methods of Piling” (Southern).

The special thanks of The Institution to Sir Harold N. Colam, joint Author of Paper, “Hammer-Blow in Locomotives: can it not be abolished altogether?” who was ineligible, as a Member of Council, to receive an Award.

Sir Clement Hindley proposed—That the thanks of this Meeting be accorded to Professor Inglis, President, for his conduct of the business as

Chairman of the Meeting. He knew what it was to preside over an Annual General Meeting, when one might expect a good deal of heckling. He thought that all the members present were very grateful to the President for the extremely kindly way in which he had conducted the proceedings and dealt with the comments that had been made on the Annual Report, and they were also grateful to him for the way in which he had dealt with the Report in his address, making dry bones come together again with living flesh on them. The President had made something interesting out of what might have appeared to be a somewhat dry affair.

Mr. W. T. Halcrow seconded the motion, which was carried unanimously.

The President, in thanking the meeting, said he was especially grateful to those who had spoken on the subject of the Report. Nothing had been said to which exception could be taken, and the discussion had not been in the slightest degree acrimonious.

The proceedings then terminated.

Paper No. 5309.

“The Lennox Road Refuse-Disposal Station, Leeds.”

By WILLIAM SPOTTISWOODE CAMERON, M. Inst. C.E.

INTRODUCTION.

IN the title of this Paper the words “Refuse-Disposal Station” are used instead of the old term “Destructor,” which the Author believes was a copyright of Messrs. Manlove Alliott & Co., Ltd. The designation “Disposal Station” would appear to be more fitting in view of the general acceptance of the axiom as to the indestructibility of matter.

The average civic waste consists of an extraordinarily heterogeneous conglomeration of material which requires a series of separate treatments before the materials to be salvaged can be separated from the residual waste so that the latter can be disposed of. Until fairly recently, authorities on the subject expressed the opinion that mechanical apparatus for handling refuse was of very limited utility; but continuous research into the subject, and modern improvements in the design of mechanical plant, have resulted in considerable labour saving, by the introduction of automatic and easily hand-operated machinery, which has enabled much hand labour to be eliminated.

At the same time the introduction of dust-extraction plant has changed the old process of refuse disposal from one nearly always associated with dust and dirt, and at times offensive, into a comparatively clean operation. So that apart from the economic advantages in the mechanization process, there is also the hygienic one.

DISPOSAL OF REFUSE IN THE CITY.

For the purpose of refuse disposal the city of Leeds was divided into four zones (Fig. 1, Plate 1).

The refuse from these zones was dealt with at the following refuse-disposal stations:—

- (1) Northern (Meanwood Road).
- (2) Eastern (Beckett Street).
- (3) Southern (Kidacre Street).
- (4) Western (Armley Road), and partly at controlled tips.

The dates of establishment of these disposal plants range from 1876 to 1898; in 1935, the Northern (Meanwood Road) Station was remodelled, with the addition of salvage-disposal plant.

THE LENNOX ROAD SCHEME.

In 1900 the Corporation, having in mind the probable desirability in the future of establishing a fifth disposal station, acquired the Lennox Road site, which has area of $2\frac{1}{2}$ acres and is conveniently situated near to Kirkstall Road—a main arterial road, for which widening proposals to 100 feet have been approved—and on the banks of the river Aire, although the river is not navigable at this point. The site and general arrangement are illustrated in Fig. 2, Plate 1.

In 1936 the Cleansing Committee were advised that owing to the growth of the city the means of refuse disposal on the western side were inadequate, as they consisted only of the direct incineration works at Armley road, which were the oldest in the city.

A report was prepared by the Director of Cleansing, who advised the erection of a disposal plant on the Lennox Road site having a capacity of 100 tons of household and trades refuse per day of 8 hours, normal continuous working.

In March 1937, a specification was drawn up by the then City Engineer, Mr. J. E. Acfield, Assoc. M. Inst. C.E., in conjunction with the then Director of Cleansing, Mr. S. Thornley, and his Deputy, Mr. A. Mann, the present Director, and tenders were invited for a scheme to include a weighbridge and office, disposal plant, and chimney, with provision for future duplication, and a garage for refuse-collecting vehicles.

The contractors were asked to submit designs to comply with the following arrangements:—

- (1) The plant should be capable of dealing with 100 tons of household refuse per day of 8 hours' continuous working at all seasons, with complete and efficient screening, and salvage of saleable materials; they were asked not to provide for the utilization of waste heat.
- (2) Special attention should be paid to prevention of the escape of dust, charred paper, and grit from the chimney shaft.

All parts of the plant where dust was likely to be caused were to be separated from the remainder of the buildings, and the escape of dust was to be controlled.

The contractors were furnished with an analysis of the house refuse to be dealt with (Appendix I), and a survey of the site.

Tenders were received in September 1937, and after consideration it was decided that the scheme prepared by Messrs. Heenan & Froude, Ltd., of Worcester, was the nearest to the Corporation's requirements, and this tender was provisionally accepted.

A Public Inquiry was held on the 22nd September 1938. The Ministry of Health granted loan sanction for £50,351 for buildings and works and £3,445 for a chimney. The construction of the disposal works was actually commenced in May 1939.

DETAILS OF PLANT.

As shown in Figs. 3 and 4, Plate 2, and Figs. 5, Plate 1, the plant is housed in three separate buildings, where the processes of collecting, screening, and incineration are carried out; all are steel-framed structures, clothed with 9 inches of brick filling.

The design provides that refuse vehicles, after passing over the weigh-bridge, tip their loads into a hopper (A) of 3,000 cubic feet capacity, having a tipping beam 40 feet long and fitted with a belt plate-conveyor (B) 9 feet wide, giving an infinite feed-variation between 2 feet per minute and 10 feet per minute.

Crude refuse is discharged by this means on to an inclined belt conveyor (C), 36 inches wide, inclined at an angle of 30 degrees to the horizontal, which leads to the screen house. This belt in turn discharges the crude house refuse into a two-way shoot, one leg of which delivers into a primary rotary screen (D), whilst the other leg leads direct to a 36-inch wide trades refuse conveyor, thus permitting the screen to be by-passed if required. An electro-magnetic drum (E), forming the head terminal of the inclined conveyor, extracts tins and ferrous scrap from the house refuse. This salvage is discharged into a chute leading to an enclosure in the baling-room below (F).

The primary rotary screen is mounted on two pairs of rubber-tired idlers, and is fitted with two sizes of mesh, namely, $\frac{3}{8}$ -inch perforations for the separation of dust from larger refuse, such as cardboard boxes, linoleum, stones, bottles, etc., and $1\frac{1}{2}$ -inch perforations to separate the cinders from this crude refuse, which passes forward to the picking belt.

The dust is conveyed by a long chute to an 18-inch dust belt conveyor, and the $1\frac{1}{2}$ -inch screenings are delivered by conveyor to the secondary rotary screen (G), which is similar to the primary screen, although rather smaller in diameter, and has the same peripheral speed. It also is fitted with mesh plates having $\frac{3}{8}$ -inch perforations for dust separation, and graded up to $1\frac{1}{2}$ -inch perforations for cinder separation.

The cinders are distributed over two patent cinder cleaners to remove the debris, which passes on to the 36-inch trades refuse conveyor for incineration with the remainder of the refuse tailings. The clean cinders fall from the bottom of the cleaners on to the 18-inch cinder conveyor; the two 18-inch belt conveyors—one for dust (H_1) and the other for clean cinders (H_2)—are inclined at an angle and lead to elevated storage hoppers (K), between the collecting-house and the screening-house, the capacities of which are 50 tons and 20 tons respectively. Each conveyor has an electro-magnetic head pulley to extract the ferrous scrap, which is dropped into container chutes, arranged in conjunction with the two storage hoppers.

Market and Bulky Refuse.—The trades refuse (from markets and shops) is tipped over a separate beam, 17 feet long, into a concrete hopper (L), having a capacity of 1,000 cubic feet. The refuse is hand-raked on to a

36-inch trades refuse belt conveyor (M), which is designed to discharge into a chute combined with the tailings chute at the delivery end of the primary rotary screen, leading direct to the 36-inch picking belt conveyor (P).

The debris from the cinder cleaners and the secondary rotary screen, and the crude household refuse when the rotary screen is by-passed, are delivered on to the 36-inch trades refuse conveyor.

An electrically-operated hoist (N) is provided to elevate bulky trades refuse such as carcasses, mattresses, etc., direct on to the top charging floor above the incinerator (T), and delivers into a specially large firing-hole on No. 8 furnace. The 36-inch picking belt conveyor (P), running at a speed of about 45 feet per minute, has a length of about 20 feet on both sides of the belt, and access is provided to allow of hand sorting. This belt receives the refuse tailings from the screens when the latter are in operation, and also the other materials as mentioned above, and delivers them on to the 36-inch distributing belt conveyor running over the full length of the incinerator.

The tailings are discharged from this conveyor (Q) into each of the cells of the incinerator by a motor-driven, travelling, throw-off carriage and a feeding chute (R) and, if required, the tailings can be deposited along the length of the charging floor (S) for hand firing at night by reversing the action of the throw-off carriage.

Incinerator.—The incinerator (T) is of the top-feed, steel-cased, firebrick-lined, flat-grate type, and has two four-cell units, each cell having a grate-area of 36 square feet, making a total grate-area of 144 square feet for each unit, and is provided with motor-fan-driven forced draught, rear combustion-chambers; the products of combustion are carried to a water-trapped dust-chamber. In case of emergency or breakdown it is possible for vehicles to tip the refuse on to the clinkering floor, in front of the cells, the refuse then being shovelled by hand through the clinkering doors on to the grates.

The hot clinkers are withdrawn from the cells in the front and an overhead ventilating duct connected to the forced-draught fans takes away any fumes. The hot clinkers are quenched under a shower of water during transit to the clinker yard outside the incinerator house.

Flues.—The flues are arranged to lead from the combustion-chambers, at an angle, to the water-trap dust-chamber and chimney. The dust-chamber is of steel-cased, firebrick-lined construction, having baffle walls, which cause the hot gases to impinge on the water in the trough, thus arresting dust, live sparks, charred paper, etc., which can be raked out periodically as mud, without interference with the operation of the plant. Dampers fitted in the flues permit isolation of either unit, as required, and control the pull of the chimney.

Dust Collecting Plant.—In order to ensure cleanliness about the works, two dust suction and collection plants have been installed; one deals with the dust arising from the refuse reception hopper, whilst the other

takes care of a number of points about the mechanical plant where dust is liable to be dispersed during the handling of the refuse.

Chimney.—The chimney is of all-brick construction, 150 feet high above ground-level, and 9 feet 9 inches diameter inside the firebrick lining, which extends the full height of the chimney. The chimney is designed to serve a final sixteen-cell incinerator, thus allowing for future duplication of the present plant. It is lined with purpose-made radial firebricks, set in fireclay. The lining is 9 inches thick for the lower 30 feet and $4\frac{1}{2}$ inches thick for the remainder of the height. There is a $1\frac{1}{2}$ -inch sealed cavity between the lining and the common brickwork.

It has been mentioned that the Lennox Road site is alongside the river, the ground-surface being about 17 feet above low-water-level. From trial holes dug on the site it was ascertained that at a depth of 5 feet 6 inches below the surface gravel and sand were found; at a depth of 17–20 feet a hard shale was found.

Foundations.—In the erection of a factory on the western boundary of the site, considerable difficulty was caused in the foundations by streams of water. It was therefore decided to have a reinforced, concrete-piled foundation raft for the chimney. The concrete foundation raft is of reinforced-concrete construction, 29 feet in diameter and 4 feet thick, the underside being 8 feet 6 inches below ground-level; it is supported on thirty-six reinforced-concrete piles, which are driven to a depth of 18 feet 6 inches below ground-level.

The Conveyor.—The inclined 36-inch belt conveyor is set at about 124 feet centres to the end terminals. It is made of rubber and canvas and is carried on trough-type idlers, spaced about 4 feet apart, on the loaded side; the return idlers are of the flat type. Continuous skirt plates and dirt-tight decking are provided along the loaded side of the conveyor. The head drum consists of an electro-magnetic pulley, totally enclosed, of the "Rotaflex" type, 24 inches diameter. Power is provided by a motor-generator set.

Between the tipping-house and the screening-house the conveyor is enclosed in a gantry, covered on the roof and on one side with asbestos cement corrugated sheeting, the other side being fitted with removable panels to allow inspection as required; a continuous timber gantry is provided to give access.

Salvage of Ferrous Metals.—As stated on p. 423, *ante*, the tins extracted are discharged into a chute, leading to the baling-room, on the ground floor; a fan blower is fitted in the chute to free them from dust and debris. The makers claim an efficiency of extraction of 80–90 per cent. of loose ferrous material, and state that of the ferrous contents so extracted not more than 10–15 per cent. by weight would be non-magnetic materials; the debris and dust blown off the tins falls into a chute leading to the 36-inch trades refuse conveyor.

Cinder-Cleaners.—Cinders from the secondary rotary screen are dis-

tributed over two patent cinder-cleaners each consisting of a short inclined belt conveyor, 18 inches wide by about 7 feet long, arranged so that its angle of inclination can be varied. The mixture of cinders and debris falls on to the belt, the clean cinders rolling to the bottom and the debris being carried upwards and deposited on to the 36-inch trades refuse belt conveyor for incineration with the remainder of the refuse tailings; the clean cinders fall from the bottom of the belt and drop on to the 18-inch belt conveyor leading to the elevated clean cinders storage hopper. The various other distributing belt conveyors mainly follow similar lines.

Picking Belt.—The process of picking stones, cullet (glass), etc., is carried out on both sides of the 36-inch picking belt conveyor. Three steel-plated bins are provided in the salvage room for storing the materials picked out of the tailings on the 36-inch picking belt conveyors, such as bones and brass or other non-ferrous metals. Two steel-plate hoppers, one for stones and the other for cullet, are arranged to discharge direct into vehicles.

Double-ram Scrap Metal Baling-Press.—This is a horizontal self-contained press (U) not requiring special foundations. It operates on the principle of preliminary pressing by auxiliary ram and final pressing by means of a main ram. The filling-box has a total length of 5 feet and a capacity of about $10\frac{1}{2}$ cubic feet. It is capable of taking articles measuring up to 3 feet 3 inches in length, 20 inches wide, and 18 inches deep, and a final compressed bale 12 inches wide, 18 inches deep, and 6–12 inches long can be obtained.

Under suitable conditions the double-ram baler is capable of producing from twenty to twenty-five bales per hour; it is designed so that it can be operated by one man.

Paper-Baler.—A power-driven paper-baler (V), which compresses and wires the waste paper, produces bales 36 inches by 24 inches by 24 inches.

Electrically Operated Plant.—All the various mechanical units are driven by electric motors, with suitable reduction gears and roller chain drives. In several cases a two-speed reduction gear is incorporated, to give variable speed-control for dealing with different quantities and qualities of refuse. The supply for the electric lighting and power is taken from the Corporation's 200-volt two-phase 50-cycle four-wire mains, and screwed galvanized conduits are used throughout the plant. A feature of the electrical installation is the number of "push-button" stop controls fitted about the plant, which can be used in an emergency without it being necessary for the operator to run to the starting switches. The direct-current supply for the magnetic pulleys is provided by means of a motor-generator set located in the screen-house.

OTHER BUILDINGS.

Apart from the plant just described, the scheme includes: a garage for refuse-vehicles, having a floor-area of 600 square yards; an office and

weigh house ; and a mess-room, with shower-bath accommodation for the operatives. These buildings are served by an independent low-pressure heating installation.

The staff operating the plant consists of ten men, in addition to the weighbridge clerk, supervisor, and maintenance and garage staff.

ACKNOWLEDGEMENTS.

The Author, who has been responsible for the work since September 1939, wishes to acknowledge the help given to him in compiling this Paper by his Chief Assistant, Mr. H. M. Chippindale, M.C., under whose general superintendence the contract was carried out, and by Mr. R. A. Frank, Chartered Engineer, who has acted as Clerk of Works since November 1939, and who prepared Appendix II, showing the successive processes through which the refuse passes.

The Paper is accompanied by five sheets of drawings, from which Plates 1 and 2 have been prepared.

APPENDIX I.

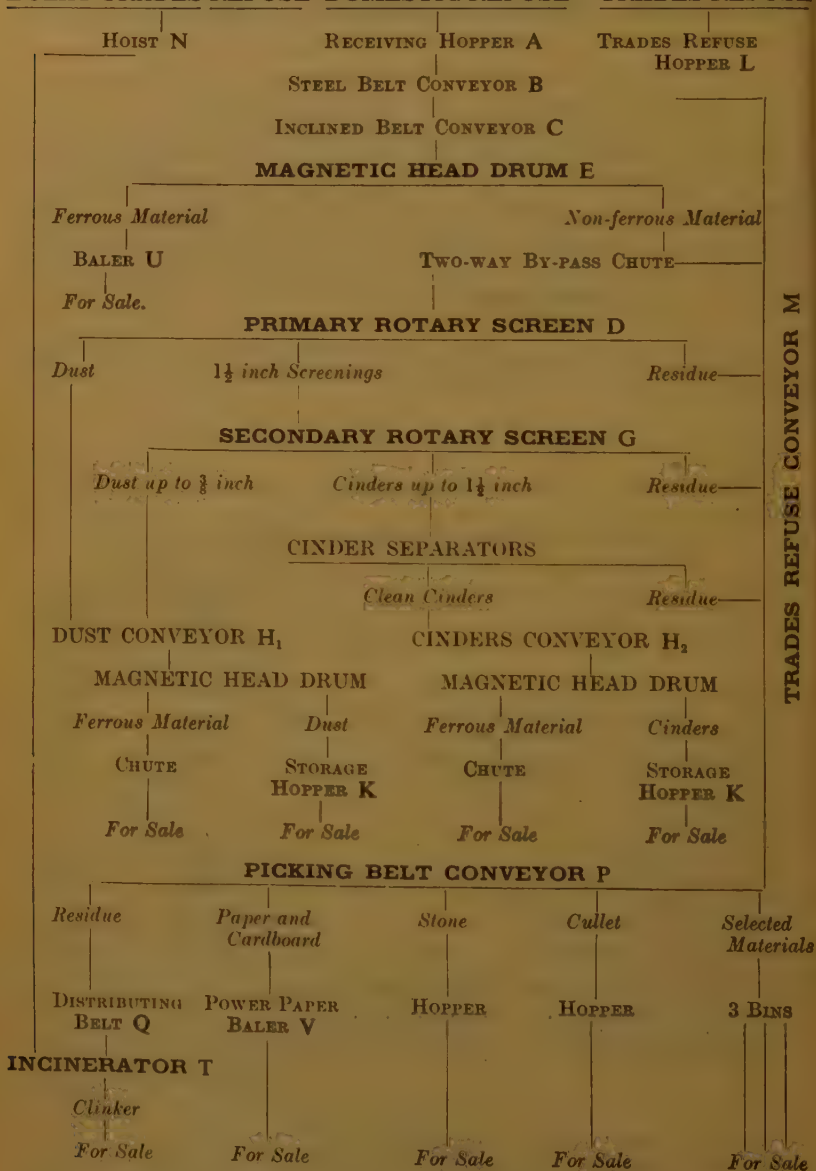
ANALYSIS OF HOUSE REFUSE TO BE DEALT WITH.

	Winter refuse : per cent.	Summer refuse : per cent.
(a) Fine dust content. (Under $\frac{5}{16}$ inch)	31.19	22.89
(b) Small cinder content. (Between $\frac{5}{16}$ inch and $\frac{3}{4}$ inch)	24.17	15.26
(c) Large cinder content. (Over $\frac{3}{4}$ inch)	10.92	6.20
(d) Vegetable and putrescible content	4.86	20.03
(e) Paper content	15.59	19.55
(f) Metal content :—		
(1) Metal containers	1.82	3.10
(2) Other metals	1.66	0.61
(g) Rag content, including bagging and all textiles	0.39	1.08
(h) Glass content :—		
(1) Bottles and jars	1.49	2.30
(2) Broken glass (cullet)	1.67	0.87
(i) Bones content	0.17	0.36
(j) Combustible debris not classified above (wood, straw, leather, etc.)	3.51	6.32
(k) Incombustible debris not classified above (bricks, stone, pottery, etc.)	2.56	1.43
	<hr/> 100	<hr/> 100
Density of refuse : cwt. per cubic yard	4.8	4.3
Density of fine dust : cwt. per cubic yard	7.7	8.6

APPENDIX II.

PROGRESS OF REFUSE.

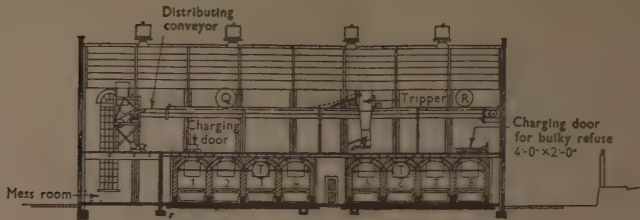
BULKY TRADES REFUSE DOMESTIC REFUSE TRADES REFUSE



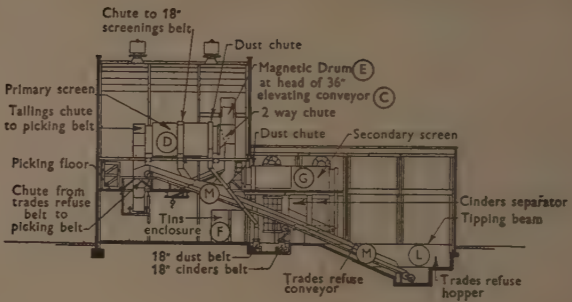
THE LENNOX ROAD REFUSE-DISPOSAL STATION, LEEDS.

PLATE 1.
THE LENNOX ROAD REFUSE-DISPOSAL
STATION, LEEDS.

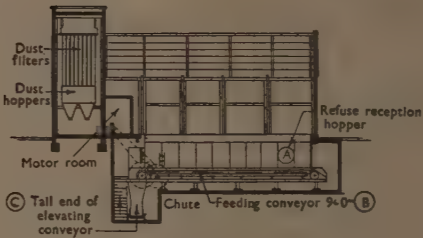
Figs 5.



SECTION C-C.



SECTION D-D.

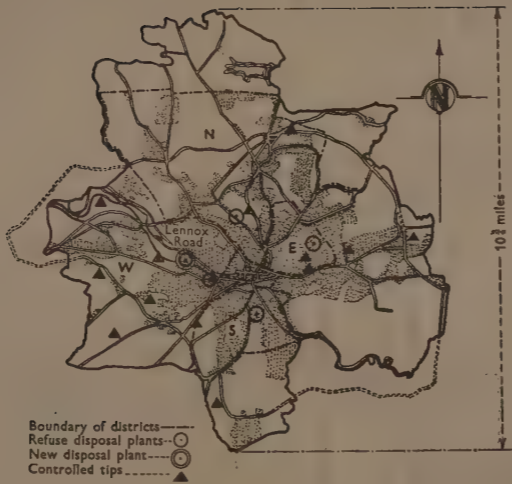


SECTION E-E.

Scale: 1 inch = 40 feet.
Feet 10 0 10 20 30 40 feet.

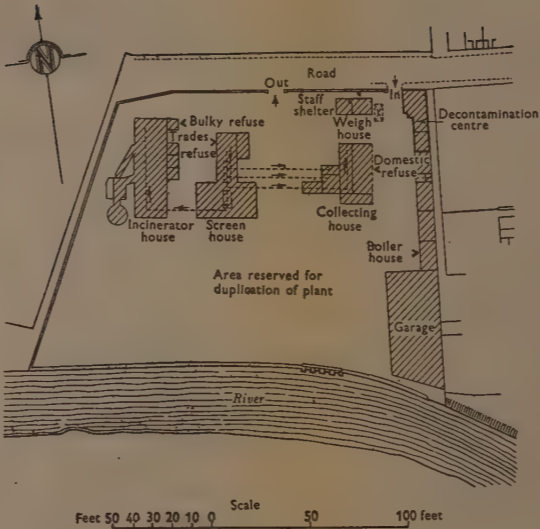
REFUSE DISPOSAL PLANT LENNOX ROAD.

FIG 1.



PLAN SHOWING REFUSE DISPOSAL DISTRICTS.

FIG 2.

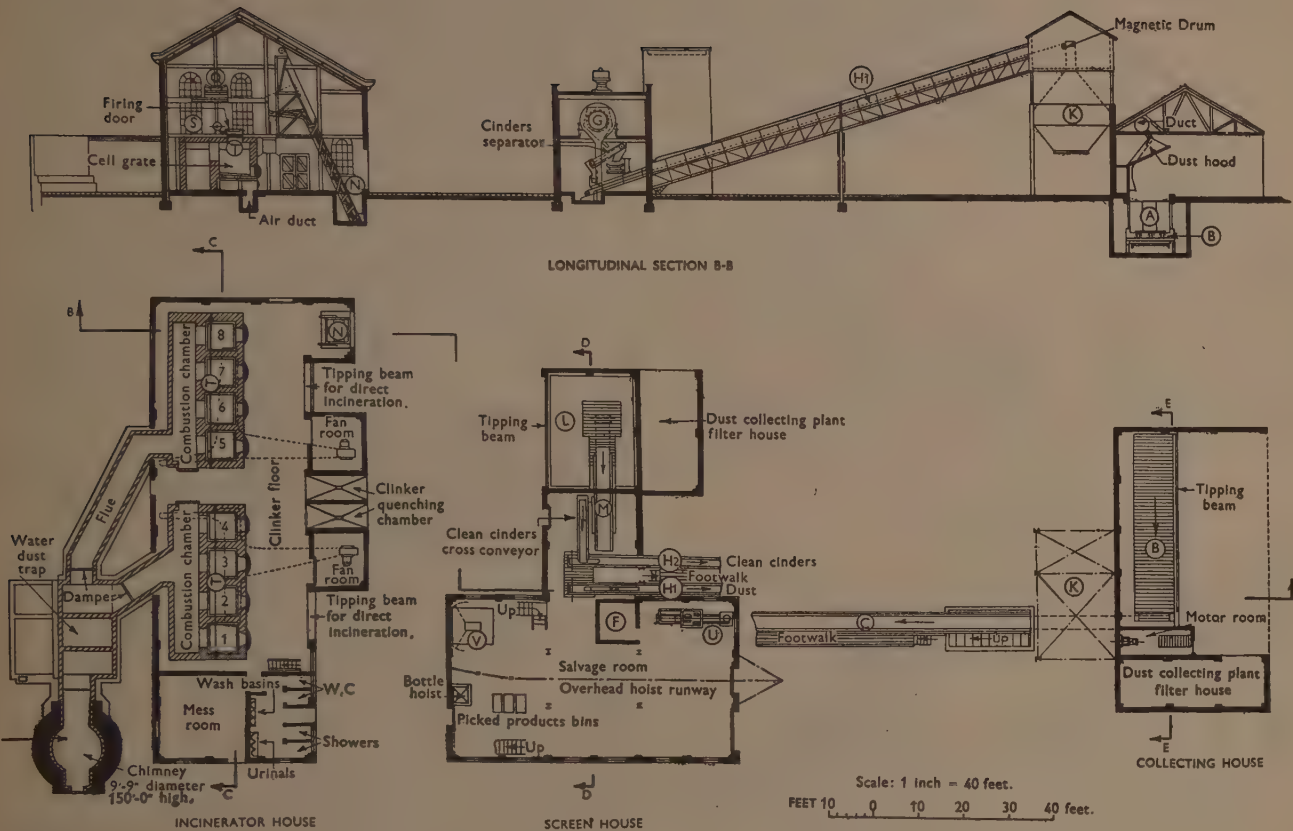


LAYOUT FOR REFUSE DISPOSAL.

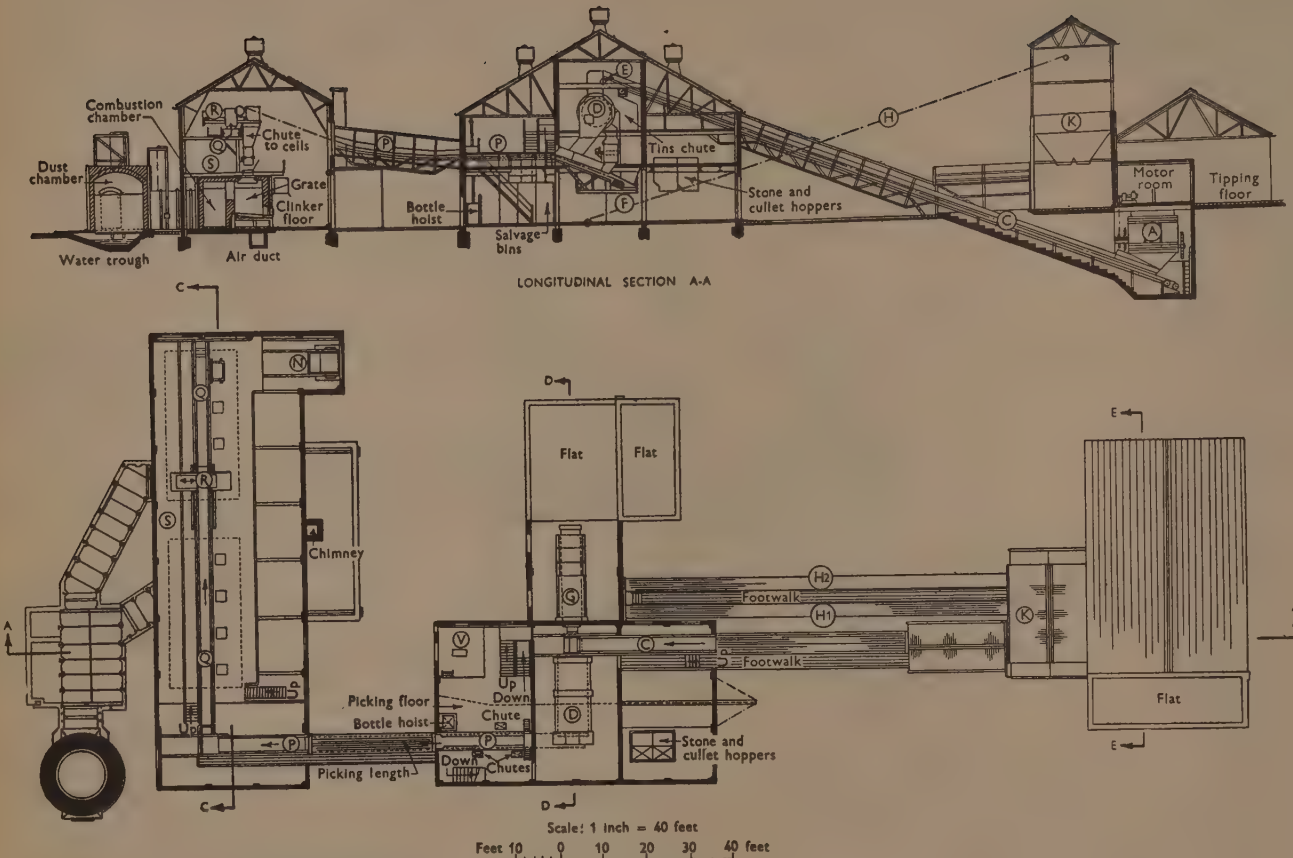
THE LENNOX ROAD REFUSE-DISPOSAL STATION, LEEDS.

PLATE 2.
THE LENNOX ROAD REFUSE-DISPOSAL
STATION, LEEDS.

Figs 3



Figs 4



REFUSE DISPOSAL PLANT, LENNOX ROAD.

JOINT MEETING WITH THE INSTITUTION
OF MECHANICAL ENGINEERS.

16 December 1941.

PROFESSOR C. E. INGLIS, O.B.E., M.A., LL.D., F.R.S.,
President Inst. C.E., in the Chair, supported by
Mr. WILLIAM ARTHUR STANIER, President Inst. Mech. E.

Discussion on

“Hammer Blow in Locomotives”¹

and on the

“Balancing of Locomotive Reciprocating Parts.”²

Sir Harold Colam, in reply, observed that he wished to express his appreciation of the remarks of the President and of the theoretical support he had given to the Authors' deductions from experimental results. It was just 40 years since Sir Harold had attended a series of lectures given by the President on the balancing of engines, and though most of it was speedily forgotten the notes were carefully preserved and twenty years later had come in useful. Therefore it was to the President that he had naturally turned in 1928 when looking for some sympathetic ear to listen to his heretical views on overbalance in locomotives, and he had found, to his relief, that the President had come more or less to the same opinions as the result of the facts disclosed by the investigations of the British Bridge Stress Committee.

Mr. Stanier had expressed doubt whether the railways in India knew what balance weight they actually put in. If he was referring to the engines as delivered from the manufacturers his doubts were well founded, as had been made clear by the facts recorded in the Paper, at all events as regards the older engines turned out before real attention began to be paid to balancing. If, however, it was his intention to suggest that the experiments on the Madras and Southern Mahratta Railway were of little value

¹ Sir Harold N. Colam and Major J. D. Watson, R.E. “Hammer Blow in Locomotives: can it not be abolished altogether?” *Journal Inst. C.E.*, vol. xvii (1941-42), p. 197 (Jan. 1942).

² E. S. Cox, “Balancing of Locomotive Reciprocating Parts.” *Journal Inst. C.E.*, vol. xvii (1941-42), p. 221 (Jan. 1942).

because the Indian engineers could not be sure that they had exactly removed all overbalance, Sir Harold had to join issue with him at once. The static balancing was carried out very carefully, and in those cases where there was no attempt at cross-balancing and the counterweights were supposed to be at 90 degrees out of phase, the method followed would have given fairly accurate results. In any case, what errors there were could not have been large and would naturally be in both directions, so that whereas in some cases the overbalance would not be wholly removed, in other cases it would be more than removed and actually turned into an underbalance. Assuming such errors to have been made, it was pertinent to point out that the subsequent experience with those underbalanced engines should be accepted as even stronger support of the general thesis of the Paper, namely that overbalance was unnecessary within the limits of weight and speed concerned. It had also to be remembered that even before the experiments started there was ample evidence that many engines with underbalance had been giving satisfactory service for years, both in India and in England.

In face of the evidence collected by the British Bridge Stress Committee Sir Harold confessed that he did not understand Mr. Stanier's statement that British railways at least knew what overbalance they put in. A few years ago they certainly did not. It might be pointed out also that for about the past 10 years the wheels of new engines delivered to India had had stamped on them the radius passing through the centre of gravity of the counterweight, and its moment in inch-pounds, both determined before the wheels were pressed onto the axles. There was little room for error in those cases, and the practice might be recommended as part of the regular inspection at the works.

It was advisable to emphasize that although the evil effects of hammer-blow had been shown up in India and England by bridge engineers, they were of even greater importance in permanent way, as had been shown clearly by the long series of investigations into stresses in railway track made in America. It was a great pity that those investigations were not better known, but unfortunately they had been recorded in many voluminous and rather formidable reports spread over many years and not easily available. A few references to them had been made in the discussion. Mr. Train's remark that mechanical engineers would be astonished at the high stresses that could be caused in rails was very true: they were so high that most people would not believe them unless they had seen the original evidence. Stresses very near to the safety-line were found often, and stresses beyond that were not uncommon. Mr. Robertson had expressed the opinion that hammer-blow did not increase rail stresses unduly, and that the calculations of those stresses were mainly speculative and had not led to any major improvements. Sir Harold begged leave to differ on all three points. Stresses in rails caused by hammer-blow were not small and their elimination was of the greater importance when the

total stresses were already dangerously high. If Mr. Robertson would refer to Technical Paper No. 245 published by the Indian Railway Board in 1925, he would, Sir Harold thought, agree that, given the track and engine data, the calculated stresses were remarkably near the observed stresses. Certainly the latter had been astonished when he made the calculations. Further, amongst improvements directly arising out of those investigations was the trailing bogie in place of the trailing axle in nearly all modern heavy engines in the United States, it having been shown by calculation and verified by observation that the trailing axle was responsible for more trouble than any other owing to its relatively great distance from adjacent axles.

The President's mathematical analysis of the probable effects of totally unbalanced reciprocating masses in reasonably heavy engines had led him to conclude that neither the resulting swerving couple nor the variation in drawbar pull, including resonance, would be of any importance. Mr. Cox, using a different method, agreed as to the swerving couple, but concluded that variation in drawbar pull would be too great for comfort and that consequently part of the reciprocating masses should be balanced. His conclusions as regards drawbar pull were shown in *Fig. 11* (page 239, *ante*) for a particular case. That showed a *calculated* maximum variation of ± 0.5 ton due to lack of overbalance at about 10 miles per hour. Sir Harold would suggest that that was of no importance whatever, seeing that a variation five times as great occurred, and was bound to occur, at a still lower speed owing to steam-thrust, and that all that mattered was the variation at the higher speeds, at which the engine spent by far the greater part of its working life, at all events in those cases where comfort was of any real importance. In the particular case the maximum was calculated to be about ± 0.35 ton for the unbalanced engine, which Mr. Cox considered to be too great because it exceeded the arbitrarily selected desirable maximum of ± 0.2 ton. Sir Harold considered that a good deal remained to be done before the figures given there could be accepted as justification of the statement that an overbalance of 50 per cent. was necessary in that case. It remained to be decided which of the two mathematical methods yielded the more correct results (which should not be difficult); more work was required before the desirable maximum could be fixed, in view of the cost of fixing it too high; and it was by no means certain that the same maximum was suitable for all cases.

It was interesting to note that the facts given by Mr. Cox on pages 244 and 245, *ante*, supported the conclusions arrived at from much more extensive experience in India, namely that leaving the reciprocating masses unbalanced did not lead to greater wear in the axle-boxes and moving parts. The theoretical demonstration on pages 204-206 indicated that there was no reason to expect it, and it was to be hoped that that ancient objection to removing overbalance would now die a well-deserved death.

Several references had been made to rough riding in light locomotives with no overbalance. Neither Sir Harold nor Major Watson had ever suggested that such engines should be totally unbalanced. Their Paper was expressly concerned with "modern" engines: it might have been better to make it quite clear that that meant "heavy" engines.

General answers to the question of how much extra load civil engineers would allow in return for a reduction of hammer-blow would be found in the British and Indian Bridge reports and in those on stresses in railway-track in America and India. No general answer, however, was of any practical use and the specific answer would depend upon local circumstances—the engines, bridges, and track concerned. As an example of what had been possible, on the Madras and Southern Mahratta Railway 17-ton axles were increased to 18-ton on the broad gauge; and on the metre-gauge 8·3-ton axles were increased to 8·7-ton in some places and 54-ton engines were allowed where 44 tons had been the maximum before. Those increases were not at all spectacular and were merely what had been asked for by the Operating Department, the available engines being what they were. In Sir Harold's opinion, they were much lower than could be allowed if required. There could be little doubt that with less of the rather extreme caution that had been allowed to clog the wheels of progress, material increases in static axle loads could be allowed. In that connexion he wished to draw attention to the diagram on page 219, *ante*, giving the total static and dynamic axle loads at normal maximum speed. That was the only form of diagram worth having, and it was to be hoped that the older form showing static loads only would soon be dead and forgotten. When he first began to collect data and record them in that way he came across a startling example of the uselessness of the older form in the first two cases. They were from different railways but by current notions were almost identical, with static wheel loads just under $8\frac{1}{2}$ tons. But at normal maximum speed (the same for both) one had a total wheel-load—including hammer-blow—of about $9\frac{1}{2}$ tons, whilst the other had no less than $14\frac{1}{2}$ tons. Yet the existing rules took them to be practically identical when deciding where they could and could not run. It was difficult to imagine anything more absurd.

It was important to realize that what could be given in return for reduction of hammer-blow was by no means the only consideration. It was within Sir Harold's personal experience—and it was very unlikely that it was unique—that enormous sums of money had been spent on renewing bridges that would not withstand the punishment from the hammer-blow of the heavier engines which it was desired to introduce. There could be no question that most of that could have been avoided by the simple expedient of cutting the hammer-blow down or eliminating it altogether. That kind of waste would go on until it was realized—as it surely would be—that it was sinful.

Summing up the case of the heavy two-cylinder engine :—

1. The President calculated that leaving the reciprocating masses unbalanced would have no untoward effects.

2. Mr. Cox agreed as to swerving couple, but calculated that the variation in drawbar pull would exceed the maximum admissible, which he placed at ± 0.2 ton. It had still to be decided which method of calculation was the more accurate, and it was by no means certain that the selected maximum was as high as it might be, or that it should be the same in all cases.

3. Actual experience on the Madras and Southern Mahratta Railway, extensive both in numbers and in time, had satisfied the engineers that overbalance could be cut out altogether within the limits of weight and speed concerned.

4. Mr. Cox, so far as he had any direct evidence, agreed that increased wear did not result.

5. Recent experience had revealed that hammer-blow could—and in some cases did—lift the wheel clean off the rail, from which it followed that wheels might often be, quite unexpectedly, in a dangerous state of near-levitation.

6. Elimination of hammer-blow meant elimination of damaging stresses, much wear and tear, and considerable expenditure; and could also result in increased operating efficiency.

It was hardly to be expected that all Locomotive Engineers would accept the heretical thesis propounded in the Paper. The Authors would be satisfied if some did and if that led to further experiments on the lines followed on the Madras and Southern Mahratta Railway, and they would await the results with confidence.

Major J. D. Watson, in reply, observed that he wished to associate himself with Sir Harold Colam's remarks, which, owing to the present circumstances and to Sir Harold's absence in India, had been made without close collaboration between the Authors. He considered that the discussion had substantiated the Authors' contention that a *prima facie* case for abolishing overbalance had been established. Mr. Train had asked for details of the deflectometer that had been used for the trials made on the Madras and Southern Mahratta. Those had been called for from India and would be forwarded to Mr. Train when they arrived.

CORRESPONDENCE ON PAPERS PUBLISHED IN THE JOURNAL DURING SESSION 1941-42.

In view of the present restrictions on paper, it is impracticable to print in this issue of the Journal the large number of communications (totalling about 130 pages) which have been received upon the undermentioned Papers, but pamphlet copies of the Correspondence may be obtained from the Secretary of The Institution upon request :—

Journal.	Paper No. *	Author.	Title.
Nov. 1941.	S.973	Wilkin.	"Concrete and the Resident Engineer."
"	5282	Wilson.	"The Calculation of the Bearing Capacity of Footings on Clay."
Dec. 1941.	5227	Haigh.	"The Emerson Barrage."
"	5274	Golder.	"The Ultimate Bearing Pressure of Rectangular Footings."
Jan. 1942.	5243	Colam and Watson.	"Hammer-Blow in Locomotives: can it not be abolished altogether?"
"	—	Cox.	"Balancing of Locomotive Reciprocating Parts."
"	5270	Cooling and Skempton.	"A Laboratory Study of London Clay."
Feb. 1942.	5276	Evans.	"Relative Merits of Wire and Bar Reinforcement in Pre-stressed Concrete Beams."
Mar. 1942.	5292	Cooling.	"Soil Mechanics and Site Exploration."
"	5297	Markwick.	"Soil Mechanics in Road and Aerodrome Construction."
Apr. 1942.	5310	Davey.	"The Surface Finishing of Concrete Structures."
June 1942.	5317	Manzoni.	"Post-War Planning and Reconstruction."
"	5300	Smith.	"Soil Mechanics: the Factor of Safety of Clay Banks."
"	5302	Evans.	"Effect of Rate of Loading on the Mechanical Properties of Some Materials."
"	5305	Skempton.	"An Investigation of the Bearing Capacity of a Soft Clay Soil."

ADDITIONAL ORIGINAL COMMUNICATIONS

RECEIVED BETWEEN THE 1ST SEPTEMBER 1941,
AND THE 31ST AUGUST 1942*.

AIR RAID SHELTERS.—Some Considerations affecting the Shape of Surface Shelters. F. H. Black. No. 5299.

BRIDGES.—Some Considerations affecting the Minimum Depth of Small Highway Bridge Girders. J. F. Pain and T. J. Upstone. No. 5295.
The Distribution of Loading Among the Girders of Small Deck-Type Highway Bridge Spans. J. F. Pain and T. J. Upstone. No. 5296.
A Method of Reducing Secondary Stresses in the Arch Ribs of Bow-string Girders by Applying Tension to the Tie-Members. R. H. Brett. No. 5303.

CONCRETE.—Economic Design of Concrete Mixes. E. E. Morgan. No. 5331.

ENGINEERING ECONOMICS.—Capital Costing and Accounting with Special Reference to Public Utility and Industrial Undertakings Employing Large, Diverse and Growing Capital Equipment. D. J. Bolton. No. 5301.

Engineering Economics. Sir Frank Gill. No. 5307.

HARBOURS.—Range Action in Harbours. G. Stewart. No. 5330.

HYDRAULICS.—Silt Load on the Behaviour of Rivers. Philip Claxton. No. 5319.

Schemes of Improvement for the River Parrett—An Investigation with the aid of a Tidal Model. Jack Allen. No. 5321.

A New Treatment of the Principles of Flow. Philip Claxton. No. 5322.

RAILWAYS.—Experiments with a Long Welded Length of Bull-Head Railway Track. J. C. Loach. No. 5312.

ROAD CURVES.—Highway Vertical Curves—The Impact Factor. Prof. F. G. Royal-Dawson. No. 5311.

Road Curvature and Superelevation. J. J. Leeming. No. 5315.

The Mathematical Design of Vertical Curves for Highways. D. G. Price. No. 5325.

SEWAGE DISPOSAL.—The Yardley Sewage Disposal Works of the Birmingham Tame and Rea District Drainage Board. F. C. Vokes and S. H. Jenkins. No. 5298.

Alignment Charts for the Design of Sewers and Other Open Channels. Frank Law. No. 5320.

* Available for reference in the Library.

SOIL MECHANICS.—The Settlement of London due to Underdrainage of the London Clay. Guthlac Wilson and Henry Grace. No. 5294.
 The Measurement of Earth Pressure on Retaining Walls. Ernest Wilkinson. No. 5314.
 The Analysis of the Failure of an Earth Dam During Construction. L. F. Cooling and H. Q. Golder.

STRUCTURES.—Results of Experiments carried out on Metallic Beams bent beyond the Elastic Limit. Prof. E. Volterra. No. 5316.
 Moment and Reaction Influence Lines of Continuous Beams of Variable Moment of Inertia and Unequal Bay Openings. A. Sanyal. No. 5326.
 Analysis of Deflections of Trusses by Method of Translations and Rotations. Shu Tao Chen, and Che Hen Chen. No. 5327.
 New Structures from Old. S. V. Gardner. No. 5328.
 Wind Pressure on Framed Structures. H. Tooley. No. 5329.

SURVEY.—Tacheometer Location Survey. L. M. Winchester. No. 5306.

TUNNELS.—Speed in Tunnelling. R. E. R. Hammond. No. 5318.
 A New Form of Reinforced-Concrete Tunnel Lining. G. L. Groves. No. 5304.

CORRIGENDA.

February 1942 Journal.—Page 360, line 2 from bottom. *For* "0.44" *read* "0.044."

April 1942 Journal.—Page 197, footnote No. 3. *For* "E. N. Bidel" *read* "E. N. Vidal."

June 1942 Journal. Page 294, Fig. 1. *For* " $n = \text{Radius}$ " *read* " $r = \text{Radius}$ "; *for* " $n \tan \phi$ " *read* " $r \tan \phi$ "; *for* " $n \sin \phi$ " *read* " $r \sin \phi$."

OBITUARY.

H.R.H. PRINCE GEORGE, DUKE OF KENT, K.G., P.C., K.T., G.C.M.G., G.C.V.O., G.B.E., the fourth son of King George V, was born on the 20th December 1902 and died on active service as the result of an aeroplane accident on the 25th August 1942. He was elected an Honorary Member of The Institution at a Meeting held on the 23rd February 1937.

GEORGE GERALD STONEY, F.R.S., was born in Dublin on the 28th November 1863, and died at his home at Newcastle-on-Tyne on the 15th May 1942.

He was educated privately and received his scientific training at Trinity College, Dublin, where in 1886 he gained the degree of B.A., and in 1887 the degree of B.E. with first place in each group of subjects and three special certificates—the highest honours obtainable. In the same year he joined the staff of the electrical department of Messrs. Clarke Chapman, Parsons & Co., and in 1898 was appointed Manager of the Mirror Department of Messrs. C. A. Parsons & Co. He was also in charge of the firm's testing department for the steam and electrical testing of engines and dynamos, and from 1893 acted as technical adviser to the firm, being intimately associated with the development of the steam-turbine, until in 1912 he started a consulting practice. From 1914 to 1917 he was Joint Secretary of the Tyneside Irish battalion of the Northumberland Fusiliers. In 1917 he was appointed Professor of Mechanical Engineering in the Manchester College of Technology and the Victoria University, Manchester. In 1926 he returned to Messrs. C. A. Parsons & Co. as Director of Research, and retained that post until his retirement in 1930. He received from Durham University the Honorary Degree of D.Sc. in 1920.

Professor Stoney was elected an Associate Member of The Institution on the 4th February 1896, and was transferred to the class of Member on the 19th December 1900. In 1905, in collaboration with the Hon. Charles A. Parsons, M. Inst. C.E., he presented a Paper entitled "The Steam Turbine¹", for which he was awarded a Watt Gold Medal. He was also a contributor to the Proceedings of the Royal Society and of the several other scientific institutions of which he was a member.

In 1894 he married Isabella Mary, daughter of the late Michael Lowes, of Corbridge-on-Tyne. There were no children of the marriage. Mrs. Stoney died in 1930.

¹ Min. Proc. Inst. C. E., vol. clxiii (1905-6, Part I), p. 167.

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NOTE.—Pages [1] to [39] can be omitted when the Journal is bound in volume form.

NOTICES

No. 8, 1941—42

OCTOBER 1942

MEETINGS, SESSION 1942—43.

OPENING MEETING.

The first meeting of the One Hundred and Twenty-Fourth Session of The Institution will take place on Tuesday, 3 November, at 5.30 p.m., when Sir John E. Thornycroft, K.B.E., will deliver his Presidential Address.

ORDINARY MEETINGS.

Arrangements have been made for the following Papers to be discussed in the first half of the Session on the dates shown below :—

1942.

Dec. 1 (Tues.) *†ORDINARY MEETING. Paper: "**Hydro-Electric Development: Some Economic Aspects**", by J. K. Hunter, B.Sc. (Eng.), and R. W. Mountain, B.Sc. (Eng.), MM. Inst. C.E. (2 p.m.).

1943.

Feb. 9 (Tues.) *††ORDINARY MEETING. Paper: "**Tunnel Linings, with Special Reference to a New Form of Reinforced-Concrete Lining**", by G. L. Groves, B.Sc. (Eng.), M. Inst. C.E. (5.30 p.m.).

JAMES FORREST LECTURE.

The James Forrest Lecture will be delivered at 2 p.m. on Tuesday, 12 January 1943, by Sir Charles G. Darwin, K.B.E., M.C., M.A., D.Sc., F.R.S., the subject being "The Extreme Properties of Matter."

* Advance proofs, for those who intend to be present at the Meetings, will be available about a fortnight before each Meeting, and copies may be obtained on application to the Secretary, Inst. C.E.

† An abstract of the Paper appears on pp. [21], [22].

†† An abstract will be printed in the January Journal.

ROAD ENGINEERING DIVISION.

The following is the programme of meetings for the first half of the Session :—

(On Tuesdays at 5.30 p.m.)

1942.

- Oct. 27. PAPERS : " **Road Curvature and Superelevation** ", by J. J. Leeming, B.Sc.,
with
" **The Mathematical Design of Vertical Curves for Highways** ", by D. G. Price, B.Sc. (Eng.), Assoc. M. Inst. C.E.

- Nov. 24. PAPER : " **The Construction of Bases for Roads and Aerodromes using Local Aggregates and Soils** ", by A. H. D. Markwick, M.Sc., and H. S. Keep, M.C., B.Sc. (Eng.), Assoc. MM. Inst. C.E.

1943.

- Feb. 16. FILM : **New York Parkways**,
and
LANTERN-LECTURE : **Foundation Problems of West Side Elevated Express Highway, New York City.**

Copies of the Papers may be obtained about a fortnight before each Meeting upon application to the Secretary.

RAILWAY ENGINEERING DIVISION.

Details of Meetings for the first half of the Session are given below :—

(On Tuesdays.)

1942.

- Oct. 20. PAPERS : " **Experiments with a Long Welded Length of Bull-Head Railway Track** ", by J. C. Loach, A.M.I.Mech.E.
(5.30 p.m.)
with
" **Preliminary Experiments with British Standard 95-lb. B.H. Track using Rails 180 feet long** ", by F. E. Campion, Assoc. M. Inst. C.E.

- Nov. 17. PAPER : " **Modern Railway Signalling** ", by A. E. Tattersall,
(5.30 p.m.) M.I.E.E.

1943.

- Jan. 19. PAPER : " **Modern Trend of Railway Engineering Practice** ", by
(2 p.m.) George Ellison, O.B.E., M. Inst. C.E.
Feb. 23. PAPER : " **Railway Construction in Great Britain under War Conditions** ", by A. S. Quartermaine, M.C., B.Sc. (Eng.), M. Inst. C.E.
(5.30 p.m.)

Copies of the Papers may be obtained about a fortnight before each Meeting upon application to the Secretary.

CIVIL ENGINEERS AND THE BUILDING INDUSTRY.**PROGRAMME OF DISCUSSION MEETINGS.**

Following the Conference held at the Institution of Civil Engineers on

Tuesday, the 25th August 1942 (an abstracted report of which appears at pp. [18]–[21], *post*) to discuss generally the question of Civil Engineering and the Building Industry, discussion meetings were arranged as under to consider the specific problems that emerged.

Tickets for the remaining three meetings may be obtained on application to the Secretary of The Institution of Civil Engineers, Great George Street, Westminster. Applicants should state whether a ticket is required for a particular meeting or for the three meetings.

1st Meeting. Tuesday, 15 September at 2.30 p.m.

The structure of the Building Industry ; its component parts ; the position of the operative ; the relation of the architect, the engineer, and the surveyor.

2nd Meeting. Tuesday, 13 October at 2.30 p.m.

The economics of Building ; a planned programme ; the financial implications in post-war reconstruction ; employment and unemployment.

3rd Meeting. Tuesday, 10 November at 2.30 p.m.

The contribution of Science and of Research to the Building Industry ; the education and training of young men entering the industry ; the part to be played by the universities and the technical schools.

4th Meeting. Tuesday, 8 December at 2.30 p.m.

Types of contracts ; the interests of the building owner ; state building ; competitive tendering ; a standard contract and a standard schedule of prices ; controls and priorities.

5th Meeting. Tuesday, 5 January at 2.30 p.m.

Management and organization ; the future of the Building Industry.

SPECIAL ANNOUNCEMENTS.

MILITARY SERVICE.

SERVICE IN ROYAL ENGINEERS.

The War Office desires to obtain particulars of Members, Associate Members, and Students of The Institution who are not already serving and are desirous of consideration for commissions in the Corps of Royal Engineers, either through the Army Officers' Emergency Reserve or after training in the ranks.

Those wishing to be considered should write to the Secretary of The Institution, giving the following information :—

- (1) Date of birth.
- (2) Private address.
- (3) Occupational classification number (*not* Industry letter). (This information, if not known, can be obtained from the National Service Officer at the local office of the Ministry of Labour and National Service.)

- (4) Registration number under the National Service (Armed Forces) Acts (if registered), and date and place of registration under these Acts.
- (5) Particulars of former military or O.T.C. Service, if any, including details of any certificates obtained.

Accepted candidates aged 31 and over will be granted direct commissions through the A.O.E.R. Those under 31 may be granted direct commissions through the A.O.E.R. or offered entry into an Officer Cadet Training Unit after about six weeks' training in the ranks.

Any not selected for commissions at any stage will be disposed of as follows :—

- (a) If by that time the individual would have been called up under the National Service (Armed Forces) Acts had he remained in civil life, he will be posted to such duties as may be thought fit.
- (b) If he would not by then have been called up, he will be discharged.

Any Member, Associate Member, or Student of The Institution receiving a calling-up notice should immediately notify the War Office (A.G.7), Hobart House, London, S.W.1, stating unit to which called, and date, in order that

- (a) if called up for service in the Royal Engineers, consideration may be given to his qualifications for commissioned rank ;
- (b) if called up for service in another Arm, the question of his transfer to the Royal Engineers may be taken up, with consequent consideration for commissioned rank.

Those writing to the War Office, in accordance with the foregoing, should send a copy of their letter to the Secretary of The Institution, who will send a confirmatory statement to the War Office.

Students of The Institution over the age of 18 years can be enlisted as "Pioneer Students"—who are tradesmen: they can do their primary training in the General Service Corps, and are then drafted to the Royal Engineers, where they undergo Sapper training. They are then considered as to their suitability as Officers and, failing that suitability, are posted within the Corps as tradesmen. All such Students desirous of consideration should write direct to the War Office (A.G.7 (L)), Hobart House, London, S.W.1.

GENERAL ANNOUNCEMENTS.

PUBLICATIONS.

The next Number of the Journal will be published on the 16th November.

An Abstract of the Paper "Earthwork in Embankments", read by Mr. R. M. Wynne-Edwards, D.S.O., M.C., M.A., M. Inst. C.E., at the Meeting of the Road Engineering Section on the 2nd June 1942, appears on pp. [17], [18], *post*.

Pamphlet copies of the full Paper, with a report of the oral discussion, may be obtained upon application to the Secretary.

INDEX TO JOURNAL.

Prior to 1941 a combined Subject- and Name-Index was printed with the October Number of the Journal. In view of the restrictions on paper it was decided last year to discontinue that practice and to send copies of the Index to those members who paid for binding cases or for complete binding. A limited edition of the Index was, however, printed for those members who did not pay a binding fee, copies being obtainable upon application to the Secretary.

The position in regard to paper has since become even more acute, and only a similar limited edition will be printed in respect of the two volumes of the Journal for Session 1941-42.

POST-WAR NATIONAL DEVELOPMENT.

A Report has been prepared by the Post-War National Development Committee, dealing with the subject of public works which could be put in hand at the conclusion of the war with a view to absorbing the large amount of labour expected to be available then. The Report, which embodies the work of various panels set up to deal with different branches of engineering work, has been submitted to the Minister of Works and Planning and to other Ministers.

A Report on Inland Water Survey has also been prepared and submitted to various Ministers.

Copies of these Reports are available to the members and may be had on application to the Secretary.

AWARDS FOR PAPERS.

The special thanks of The Institution have been given to Sir Harold N. Colam, joint Author of the Paper on "Hammer-Blow in Locomotives: can it not be abolished altogether?", who, as a Member of Council, was ineligible to receive an Award.

The undermentioned awards have been made for Papers read at Ordinary Meetings in Session 1941-42 :—

Telford Premiums to :—

- L. F. Cooling, M.Sc., for his Paper on "Soil Mechanics and Site Exploration."
 Albert Parker, D.Sc., for his Paper on "Treatment of Water for Domestic and Industrial Requirements—Some Problems and Methods."
 H. J. B. Manzoni, C.B.E., M. Inst. C.E., for his Paper on "Post-War Planning and Reconstruction."
 A. H. D. Markwick, M.Sc., Assoc. M. Inst. C.E., for his Paper on "Soil Mechanics in Road and Aerodrome Construction."
 Norman Davey, B.Sc. (Eng.), Ph.D., M. Inst. C.E., for his Paper on "The Surface Finishing of Concrete Structures."

A Webb Prize to :—

- J. D. Watson, B.Sc. (Eng.), Assoc. M. Inst. C.E., joint Author of the Paper on "Hammer-Blow in Locomotives : can it not be abolished altogether ?"

The following Award has been made for a Student's Paper read in Session 1941-42 before the Southern Association :—

A Miller Prize to :—

- M. C. Privett, Stud. Inst. C.E., for his Paper on "Modern Methods of Piling."

The undermentioned awards have also been made :—

- (1) For Papers published (without oral discussion) in Session 1941-42 :—

The Coopers' Hill War Memorial Prize to :—

- F. F. Haigh, B.Sc., B.E., Assoc. M. Inst. C.E., for his Paper on "The Emerson Barrage."

Telford Premiums to :—

- L. F. Cooling, M.Sc., and A. W. Skempton, M.Sc., Assoc. M. Inst. C.E., jointly for their Paper on "A Laboratory Study of London Clay."
 Jack Allen, D.Sc., Assoc. M. Inst. C.E., for his Paper on "An Investigation of the Stability of Bed Materials in a Stream of Water."
 A. W. Skempton, M.Sc., Assoc. M. Inst. C.E., for his Paper on "An Investigation of the Bearing Capacity of a Soft Clay Soil."
 H. Q. Golder, M.Eng., Assoc. M. Inst. C.E., for his Paper on "The Ultimate Pressure of Rectangular Footings."
 Guthrie Wilson, S. M., B.Sc. (Eng.), M. Inst. C.E., for his Paper on "The Calculation of the Bearing Capacity of Footings on Clay."
 V. F. Bartlett, B.Sc. (Eng.), M. Inst. C.E., and J. Y. Danks, B.Sc. (Eng.), Assoc. M. Inst. C.E., for their Paper on "Steel Pedestals for Heavy Columns."
 R. H. Evans, M.Sc., Ph.D., Assoc. M. Inst. C.E., for his Paper on "Relative Merits of Wire and Bar Reinforcement in Pre-Stressed Concrete Beams."
 J. F. H. Nicolson, M.C., Assoc. M. Inst. C.E., for his Paper on "The Burma-Yunnan Road."

Professor Max Born, D.Sc., F.R.S., and H. L. D. Pugh, B.Sc., for their Paper on "Vibration of a Thin Vertical Cantilever caused by a Damped Harmonic Disturbance of the Ground."

R. H. Evans, M.Sc., Ph.D., Assoc. M. Inst. C.E., for his Paper on "Effect of Rate of Loading on the Mechanical Properties of some Materials."

Professor A. J. S. Pippard, M.B.E., D.Sc., M. Inst. C.E., and Letitia Chitty, M.A., for their Papers on "Repeated Load Tests on a Voussoir Arch" and "The Stresses in an Extensible Suspension Cable."

J. A. Posford, M.A., Assoc. M. Inst. C.E., for his Paper on "The Construction of an Arch Dam for Temporary Work."

E. C. Smith, Ph.D., M.Sc. (Eng.), M. Inst. C.E., for his Paper on "Soil Mechanics: the Factor of Safety of Clay Banks."

(2) For Papers read before the Road Engineering Division and the Railway Engineering Division in Session 1941-42 :—

Road Engineering Division.

Telford Premiums to :—

Robert Slater, M.Sc., Assoc. M. Inst. C.E., for his Paper on "Road Experiments on the Design of Thin Bituminous Surfacing."

C. S. Chettoe, B.Sc., M. Inst. C.E., for his Paper on "The Effects of Modern Road Layout on Bridge Design."

R. M. Wynne-Edwards, D.S.O., M.C., M.A., M. Inst. C.E., for his Paper on "Earthwork in Embankments."

Railway Engineering Division.

A Trevithick Premium to :—

W. K. Wallace, M. Inst. C.E., for his Paper on "Permanent Way Tests and Practice on the London Midland and Scottish Railway."

A Telford Premium to :—

Arthur Dean, M.Sc. (Eng.), Assoc. M. Inst. C.E., for his Paper on "The Repair of War Damage to Railway Way and Works in the London Area, 1940 and 1941."

INGENUITY COMPETITION.

The Council have, after consideration of the fourteen entries received for the Competition in 1942, awarded the prize of twenty-five guineas to :—

D. G. McGarey, B.Sc. (Eng.), Assoc. M. Inst. C.E., for his Paper entitled "Emergency Repairs to Weedon Embankment on the Grand Junction Canal."

The Paper will be published in a subsequent Number of the Journal and some of the other entries may also be published later on.

ROAD ENGINEERING DIVISION AND RAILWAY ENGINEERING DIVISION.

Corporate Members at home have been advised recently of the formation of the above Divisions, the objects of which are given below :—

- (a) the general advancement of the science and art of Road/Railway Engineering in any and all of its aspects and the exchange of information and ideas relating thereto amongst the members of The Institution and otherwise.
- (b) the holding of meetings of the Divisions during the course of The Institution Session for the reading and discussion of communications upon subjects relating to Road/Railway Engineering.
- (c) the organization of summer or autumn meetings of the Divisions in London, or elsewhere, if thought desirable, and of visits to engineering works.
- (d) the publication of Papers, communications or other documents in the Institution Journal or otherwise.
- (e) the fostering of research relating to Road/Railway Engineering Developments.

The programmes of Meetings for the first half of this Session appear at p. [2].

STRUCTURAL AND BUILDING ENGINEERING DIVISION.

The Council have now resolved that a Structural and Building Engineering Division of The Institution is to be formed on lines similar to those of the Road Engineering Division and Railway Engineering Division.

Notice of the inception of this Division, with a registration form, is sent with this Number of the Journal to all Home Corporate Members.

It is probable that the Council will promote other Engineering Divisions in the near future, of which due notice will be given to members.

FACILITIES FOR VISITORS FROM OVERSEAS.

The President and Council of The Institution of Civil Engineers have to advise members of kindred engineering and scientific societies in the British Empire and in other countries abroad that they will be glad to accord to them, if suitably introduced, the privileges of attending the Meetings of this Institution and of using the Institution Library and Reading Rooms while in England. Further, they will be pleased to assist such visitors, if they so desire it, in obtaining facilities to visit engineering works in this country, where visits are permitted, through letters of introduction to members of The Institution.

PRESENTATION OF PAPERS TO THE INSTITUTION.

The Council invite Original Communications on subjects of professional interest.

It has been found that Papers of 5,000 words and less have dealt adequately with one aspect of a subject, and, when discussed, have given

rise to an effective discussion. A Paper of 8,000 or 9,000 words is long enough for the presentation of any subject to The Institution, and if this limit is exceeded, it will be doubtful whether the Paper can be accepted for publication except in an abridged form, as the space available in the Journal is limited. All Papers approved for publication are liable to such abridgment or condensation as the Council may deem desirable, subject to the submission of proofs to Authors before publication. Short Papers of about 1,500 words on subjects of special interest are also welcomed.

Papers can be received and considered only in a complete and definitive form, accompanied by all necessary illustrations. If such drawings or diagrams have to be prepared by an Author specially for the purposes of a Paper, application should first be made to the Secretary for more detailed information as to the style of their preparation. The Institution bears all costs of reproduction and publication, and the cost of reproduction is naturally one of the factors influencing a decision as to publication.

Manuscripts.

(1) All manuscripts should be typewritten (double spacing) on foolscap paper, on one side of the paper only. A duplicate copy of the MS. should be furnished, which will, if desired, be returned to the Author in the event of the Paper not being approved for publication in any form.

(2) Manuscripts should bear the signature of the Author.

(3) In writing, the use of the first person should be avoided, the writer being referred to as "the Author."

(4) The first spelling in the "Concise Oxford Dictionary" should be used.

(5) All mathematical symbols should be defined, and engineering symbols used should be in accordance with the recommendations of the British Standards Institution. Abbreviations should not be used in the text.

(6) Reference to other publications should give the name and initials of the Author, the title of the article or book, the name and volume number of the Journal (where applicable), the date and place of publication, and the number of the page.

Communications must be forwarded to the Secretary. There is no specified date for the delivery of MSS., as when a Paper is not in time for one session it may be dealt with in a subsequent one.

Papers which have been read at the Meetings of other Societies, or have been published, will not be accepted. According to the By-laws every Paper presented to The Institution is deemed to be its property, and may not be published without the consent of the Council.

Premiums.

For approved Papers the Council have the power to award Premiums

arising out of Funds bequeathed for the purpose, particulars of which will be supplied on application to the Secretary.

In the adjudication of the Premiums no distinction will be made between Papers received from members of The Institution or others, except where eligibility is limited by the directions of the donors.

HONOURS.

The Council have much pleasure in congratulating the following members on the Distinctions conferred upon them :—

George Medal :—

WATERS, George Frederick, B.A., B.S.I.

Associate Member.

Distinguished Service Order :—

PRENDERGAST, William Hilary, B.E. (Lieut.-Col. I.E.).

Member.

BIRTHDAY HONOURS LIST, JUNE 1942.

Knight Bachelor :—

FRANK, Thomas Peirson

Vice-President.

Order of the British Empire—Civil Division :—

WALKER, Hubert Edmund, O.B.E.

Member.

C.B.E. MACDONALD, Farquhar Victor

Associate Member.

WATSON, William Law

Associate Member.

O.B.E. DODD, Arthur Hughes, B.Eng.

" "

M.B.E. HALDANE, William Paul, B.Sc.

Member.

Order of the Indian Empire :—

C.I.E. BROWN, Gilbert Alexander Murray, O.B.E., B.Sc.

Member.

GRANT, John Leslie

Associate Member.

TRANSFERS AND ADMISSIONS.

Since the 12th May 1942, the Council have transferred 23 Associate Members to the class of full Members, and have admitted 101 Students.

DEATHS AND RESIGNATIONS.

DEATHS.

H.R.H. GEORGE, DUKE OF KENT, K.G., P.C., K.T., G.C.M.G.,
G.C.V.O., G.B.E. (E. 1937.)

Hon. Member.

ABBOT, Frederick William, C.B.E. (E. 1893. T. 1916.)

Member.

BENTLEY, William. (E. 1918. T. 1935.)

"

BROWN, Harold Henry Lane. (E. 1895. T. 1904.)

"

CARSTAIRS, Andrew. (E. 1921. T. 1942.)

"

COALES, Francis George. (E. 1915. T. 1930.)

"

GIBSON, Joseph Hamilton, O.B.E., M.Eng. (E. 1919.)

"

GUTTERIDGE, Alan Gordon, M.C.E., M.Sc. (E. 1934.)

"

HESKETH, Everard. (E. 1880. T. 1893.)

"

HUTCHINGS, Charles Arthur. (E. 1889. T. 1920.)

"

JUFF, John Francis. (E. 1904. T. 1914.)	Member.	
MILLER, John, LL.D., B.E. (E. 1923.)	"	
PARKINSON, Richard Marion. (E. 1882. T. 1914.)	"	
PEACE, George Henry. (E. 1887. T. 1889.)	"	
SELLS, Charles de Grave, O.B.E. (E. 1882. T. 1895.)	"	
SHELDON, William John. (E. 1892. T. 1900.)	"	
STONEY, George Gerald, F.R.S. (E. 1896. T. 1900.)	"	
UDWIN, Maurice, B.Sc. (E. 1931. T. 1934.)	"	
WAKEFORD, John Percy. (E. 1894. T. 1914.)	"	
WILLIAMS, John Harcourt. (E. 1905. T. 1921.)	"	
WYNNE, Sir Trevredyn Rasleigh, K.C.S.I., K.C.I.E. (E. 1904.)	"	
BAILLIE, James Picton. (E. 1889.)	Associate Member.	
BARNES, Robert Samuel Wemyss. (E. 1887.)	"	"
BROWN, William Henry, M.C., B.Sc. (E. 1913.)	"	"
BURTON, William Ernest Hadfield. (E. 1906.)	"	"
FRENCH, William Henry. (E. 1928.)	"	"
GLADWYN, Sidney Charles, M.B.E. (E. 1911.)	"	"
GRIXONI, Cyril Reynold, B.Sc. (E. 1927.)	"	"
KENDALL, Cyril Lambert, B.Sc. (E. 1931.)	"	"
*KENNEDY, John Ross, D.S.O., B.Sc. (E. 1931.)	"	"
KETLEY, Herbert Constant, B.Sc. (E. 1935.)	"	"
McCOLGAN, Albert John. (E. 1918.)	"	"
MURPHY, Frank Eric Bean, B.Sc. (E. 1933.)	"	"
*O'CONNOR, Frank Ronald Escott. (E. 1930.)	"	"
PAWLEY, Francis Adolphus. (E. 1889.)	"	"
PONSONBY, Roy Evelyn. (E. 1921.)	"	"
ROCHE, William, C.I.E., B.E. (E. 1910.)	"	"
ANDERSON, Gordon William. (A. 1934.)	Student.	
*BRIGGS, Antony Herbert Lindsay. (A. 1939.)	"	
*JARDINE, Alexander Russell, B.A. (A. 1936.)	"	
JONES, Arthur Alfred. (A. 1940.)	"	
*LEGGATT, James, Jun. (A. 1940.)	"	
*NASH, Harold Hall. (A. 1939.)	"	
*SMITH, Andrew Henry, B.A. (A. 1938.)	"	
*WEBSTER, Stanley Frederick. (A. 1939.)	"	
* On active service.		

RESIGNATIONS.

DUNDERDALE, Roland John, M.A. (E. 1910. T. 1932.)	Member.	
SYKES, Edward Francis. (E. 1908. T. 1921.)	"	
BRAYSHAY, Alfred William. (E. 1910.)	Associate Member.	
COCKSHOTT, Edgar Harry. (E. 1906.)	"	"
CORNISH, James Easton. (E. 1904.)	"	"
HORSFIELD, William Thornton. (E. 1911.)	"	"
MARKHAM, Cecil Carey. (E. 1903.)	"	"
ROBSON, Thomas. (E. 1904.)	"	"
ROUQUETTE, Gordon Kenitz. (E. 1920.)	"	"
CASLAKE, Eric Rowland. (A. 1937.)	Student.	
STEPHENSON, Roderick Alan, B.Eng. (A. 1939.)	"	
WICKSTEED, Alan. (A. 1936.)	"	

A SELECTIVE LIST OF RECENT ADDITIONS TO THE LIBRARY.

[Journals, Proceedings of Societies, etc., are not included.]

AERIAL PHOTOGRAPHY. *See* PHOTOGRAPHY.

AIRCRAFT. ELZEA, L. S. "Aircraft Welding." 1942. McGraw-Hill. 14s.

***BIOGRAPHY.** FALK, B. "The Bridgewater Millions. A Candid Family History." 1942. Hutchinson. 18s.

BRICKS. PLUMMER, H. C., and REARDON, L. J. "Brick Engineering." 1939. Structural Clay Products Inst., Washington. 20s.

***BRIDGES.** "Failure of the Tacoma Narrows Bridge. Report." 1941. Pasadena: Calif. Inst. Techn. No price.

CHEMICAL WARFARE. *See* WAR.

CHEMISTRY. *See* EXPLOSIVES.

CIVIL DEFENCE. BINGER, W. D., and BAILEY, H. H. "What the Citizen should know about Civilian Defense." 1942. Norton. \$2.50.

— LAWSON, J. K. "Rescue Work." 1942. Crowther. 3s. 6d.

COMPRESSION-IGNITION ENGINES. *See* DIESEL ENGINES.

CONVEYING. HETZEL, F. V., and ALBRIGHT, R. K. "Belt Conveyors and Belt Elevators." 3rd ed. 1941. Chapman & Hall. 36s.

DELTAS. STRICKLAND, C. "Deltaic Formation, with special reference to the hydrographic processes of the Ganges and the Brahmaputra." 1940. Longmans. 9s.

DIESEL ENGINES. GOLDINGHAM, A. H. "High Speed Diesel or Compression-Ignition Oil Engines." 1942. Spon. 15s.

ECONOMICS. *See* IRON AND STEEL WORKS.

ELECTRICAL ENGINEERING. MACCALL, W. T. "Electrical Engineering, Vol. 2." 1942. University Tutorial Press. 15s.

ELECTRICITY—GENERATION. "PROTON." "Private Generating Plant." 1942. Newnes. 7s. 6d.

ELECTRICITY—RECTIFICATION. ROSSLYN, J. "Power Rectifiers." 1941. Newnes. 7s. 6d.

EXPLOSIVES. DAVIS, T. L. "Chemistry of Powder and Explosives, Vol. 1." 1941. Chapman & Hall. 16s. 6d.

FACTORY INSPECTION. DJANG, T. K. "Factory Inspection in Great Britain." 1942. Allen & Unwin. 12s. 6d.

FIRE AND FIRE PROTECTION. CROSBY, U. C., and others. "Handbook of Fire Protection." 9th ed. 1941. National Fire Protection Association, Boston. 27s.

FOREMANSHIP. DAVIS, H. McF. "Introduction to Foremanship." 1942. MacDonald & Evans. 8s. 6d.

FOUNDATIONS. INSTITUTION OF STRUCTURAL ENGINEERS. "Report on Foundations. 1. Foundations in Disturbed Ground." 1942. The Institution. 1s.

— MORSON, A. "Erection of Heavy Reciprocating Machinery on Concrete Foundations." 1942. Diesel Engine Users' Association. 7s.

GAS. MAIER, C. G. "Mechanical Concentration of Gases." Bulletin 431, U.S. Bur. Mines. 1940. Washington. 20 cents.

GAS PRODUCERS. KISSIN, I. "Gas Producers for Motor Vehicles and their Operation with Forest Fuels." 1942. Imperial Forestry Bureau, Oxford. 3s.

— NATIONAL FEDERATION OF GAS COKE ASSOCIATIONS. "Producer Gas Plant for Industrial Purposes." 1942. The Federation, 1 Grosvenor Place, S.W.1. 5s.

- GEARS. MERRITT, H. E. "Gears." 1942. Pitman. 30s.
- IGNITION. MORGAN, J. D. "Principles of Ignition." 1942. Pitman. 12s. 6d.
- INDIA. *See* DELTAS.
- INDUSTRIAL FATIGUE. NATIONAL RESEARCH COUNCIL, U.S.A. "Fatigue of Worker and its relation to Industrial Production." 1941. Reinhold. 15s.
- IRON AND STEEL WORKS. BURN, D. L. "Economic History of Steel-Making, 1867-1939." 1940. Cambridge University Press. 27s. 6d.
- MEYENBERG, F. L. "Economic Control of Iron and Steel Works." 1942. Chapman & Hall. 25s.
- LAND DRAINAGE. NICHOLSON, H. H. "Principles of Field Drainage." 1942. Cambridge University Press. 15s.
- LIGHTING. AMICK, C. L. "Fluorescent Lighting Manual." 1942. McGraw-Hill. 21s.
- LIGHTNING. BRYANT, J. M., and NEWMAN, M. "Lightning Discharge Investigation. 1." Technical Paper No. 38. 1942. Eng. Exp. Stn., University of Minnesota. No price.
- MACHINE SHOP. *See* PRODUCTION.
- MAGNETIC TOOLS. MOLLOY, E., *Ed.* "Magnetic Tools and Appliances in Engineering Production." 1942. Newnes. 7s. 6d.
- MANUFACTURING. BUCKINGHAM, E. "Interchangeable Manufacturing." 2nd ed. 1941. Machinery Publ. Co. 15s. 6d.
- RAUTENSTRAUCH, W. "Design of Manufacturing Enterprises." 1941. Pitman. 21s.
- MATERIALS. GILKEN, H. J., and others. "Materials Testing." 1941. McGraw-Hill. 19s.
- MARIN, J. "Mechanical Properties of Materials and Design." 1942. McGraw-Hill. 21s.
- See also* STRENGTH OF MATERIALS.
- MATHEMATICS. BAKST, A. "Mathematics: its Magic and Mastery." 1941. Chapman & Hall. 21s.
- HARDY, G. H. "A Course of Pure Mathematics." 8th ed. 1941. Cambridge University Press. 12s. 6d.
- — "A Mathematician's Apology." 1941. Cambridge University Press. 3s. 6d.
- TOFT, L., and MCKAY, A. D. D. "Practical Mathematics." 2nd ed. 1942. Pitman. 15s.
- MECHANICS. COLLECTIVE. "Theodore von Kármán Anniversary Volume. Contributions to Applied Mechanics." 1941. California Institute of Technology, Pasadena. 22s. 6d.
- LOW, B. B. "Engineering Mechanics." 1942. Longmans. 12s. 6d.
- SYGNE, J. L., and GRIFFITHS, B. A. "Principles of Mechanics." 1942. McGraw-Hill. 31s. 6d.
- *See also* STATISTICS.
- METALS. *See* ORES. STRENGTH OF MATERIALS.
- MICA. CHOWDHURY, R. R. "Handbook of Mica." 1939. Thacker. 30s.
- MICROSCOPY. CORRINGTON, J. D. "Working with the Microscope." 1941. McGraw-Hill. 21s.
- MILITARY ROADS. *See* ROADS.

- MOTION STUDY. SAMPTER, H. C. "Motion Study." 1941. Pitman. 10s. 6d.
- ORES. HILLS, F. G. "Technical Analysis of Ores and Metallurgical Products." 2nd ed. 1939. Spon. 15s.
- PAPER. ROWLEY, F. B., and others. "Pulp, Paper, and Insulation Mill Waste Analysis." 1942. Bulletin 19, Eng. Exp. Stn., Univ. of Minnesota. No price.
- PHOTOGRAPHY—AERIAL. BAGLEY, J. W. "Aerophotography and Aerosurveying." 1941. McGraw-Hill. 31s. 6d.
- PHOTOMICROGRAPHY. ALLEN, R. M. "Photomicrography." 1941. Van Nostrand. 32s. 6d.
- PLUMBING. MATTHIAS, A. J., Jr. "How to Design and Instal Plumbing." 2nd ed. 1942. American Technical Society. 21s.
- POWER STATIONS. GAFFERT, G. A. "Steam Power Stations." 2nd ed. 1940. McGraw-Hill. 31s. 6d.
- PRODUCTION. KOEPKE, C. A. "Plant Production Control." 1941. Chapman & Hall. 24s.
- TOWN, H. C., *Ed.* "Machine Shop Year Book & Production Engineers' Manual." 1942. Elek. 25s.
- PULP. *See* PAPER.
- RADIO ENGINEERING. ECKERSLEY, P. P. "The Power behind the Microphone." 1941. Cape. 10s. 6d.
- REFRACTORIES. SEARLE, A. B. "Refractory Materials." 3rd ed. 1940. Griffin. 45s.
- REFRIGERATION. WILLIAMS, H. "Mechanical Refrigeration." 5th ed. 1941. Pitman. 30s.
- REFUSE DISPOSAL. AMERICAN PUBLIC WORKS ASSOCIATION. "Refuse Collection Practice." 1940. The Association, Chicago. 30s.
- REPORT WRITING. RHODES, F. H., and JOHNSON, H. F. "Technical Report Writing." 1941. McGraw-Hill. 9s.
- ROADS. AMERICAN SOCIETY OF CIVIL ENGINEERS. "Military Roads in Forward Areas" and "Surveys of Highway Engineering Positions and Salaries." 1941. Manuals of Engineering Practice 23 and 24. The Society, New York. 9s. and 8s. respectively.
- HEWES, L. J. "American Highway Practice, Vol. 1." 1942. Chapman & Hall. 30s.
- STATISTICS. KENNEY, J. F. "Mathematics of Statistics, Part 1." 1941. Van Nostrand. 12s. 6d.
- SIMON, L. E. "An Engineer's Manual of Statistical Methods." 1941. Chapman & Hall. 16s. 6d.
- STEEL. THUM, E. E., *Ed.* "Modern Steels." 1939. American Society of Metals Cleveland. 21s.
- STRENGTH OF MATERIALS. BRENNEMAN, J. W. "Strength of Materials." 1941. McGraw-Hill. 10s. 6d.
- TIMOSHENKO, S. "Strength of Materials." 2 vols. 2nd ed. 1941. Macmillan. 50s.
- STRUCTURES. SINGLETON, J. "Manual of Moment Design." 1941. Ives, Topeka Kansas. 24s.
- SURVEYING. *See* PHOTOGRAPHY—AERIAL.
- TELESCOPES. WOODBURY, D. O. "The Glass Giant of Palomar." 1941. Dodd Mead, New York. 21s.

TESTING. *See* MATERIALS.

TRIGONOMETRY. BAIN, A. W. "Trigonometry Simplified." 1942. Foyle. 6s.

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— MANLEY, R. G. "Fundamentals of Vibration Study." 1942. Chapman & Hall. 13s. 6d.

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* — RICHARDS, J. M., *Ed.* "The Bombed Buildings of Britain: a record of Architectural Casualties, 1940-1." 1942. Architectural Press. 15s.

— WACHTEL, C. "Chemical Warfare." 1941. Chapman & Hall. 24s.

WATER PURIFICATION. NORCOM, G. D., and BROWN, K. W. "Water Purification for Plant Operators." 1942. McGraw-Hill. 17s. 6d.

WATER SUPPLY. LOUDAN, J. "In Search of Water, being a History of the Belfast Water Supply." 1940. Mullin, Belfast. 10s. 6d.

WELDING. *See* AIRCRAFT.

WIRELESS. *See* RADIO.

* *The foregoing books, with the exception of those marked with an asterisk, may be borrowed from the Loan Library.*

LOCAL ASSOCIATIONS.

The following arrangements have been made for forthcoming meetings of the Local Associations. The arrangements are in the hands of the Committees of the Associations concerned, and all communications respecting them should be addressed to the respective Honorary Secretaries:—

BIRMINGHAM AND DISTRICT ASSOCIATION.

1942.

Oct. 24. Films.—The Failure of the Tacoma Narrows Suspension Bridge and the Erection of the Rainbow Bridge, Niagara Falls.

Nov. 12. "The Replanning of Coventry", by D. E. E. Gibson, M.A.

Nov. 21. Discussion on "Improvisation under War Conditions", to be introduced by A. A. Barnes, M. Inst. C.E.

BRISTOL AND DISTRICT ASSOCIATION.

Nov. 5. Lantern lecture.—The Holland Tunnel, New York.

Dec. 3. Film.—New York Parkways.

1943.

Jan. 7. Film.—Erection of the Rainbow Bridge, Niagara Falls.

EDINBURGH AND DISTRICT ASSOCIATION.

1942.

Nov. 11. Films.—New York Parkways and Construction of the Pennsylvania Turnpike.

Dec. 9. "Planning of Inland Waterways and Hydro-Electric Schemes in Poland", by Henryk Herdick.

1943.

Jan. 13. Film.—Erection of the Rainbow Bridge, Niagara Falls.

NORTH-WESTERN ASSOCIATION.

1942.

- Oct. 24. Opening Meeting. Address by the Chairman, Mr. E. C. Oakes, M. Inst. C.E.

NORTHERN IRELAND ASSOCIATION.

- Oct. 19. Opening Meeting. Address by the Chairman, Mr. S. H. W. Middleton, B.A., B.A.I., M. Inst. C.E.

SOUTH WALES AND MONMOUTHSHIRE ASSOCIATION.

- Nov. 28. Film.—Erection of the Rainbow Bridge, Niagara Falls (at Cardiff).

SOUTHERN ASSOCIATION.

- Oct. 17. "The Civil Engineer and Post-War Planning"; further discussion on Mr. H. J. Manzoni's Paper, to be introduced by Mr. D. Halton Thomson, M.A., M. Inst. C. E. (at Portsmouth).
 Nov. 14. Meeting to be arranged (at Southampton).
 Nov. 21. Joint Meeting with the Southern Branch of the Institution of Mechanical Engineers. The Thomas Hawksley Lecture, on "Recent Developments in Refrigeration" (at Portsmouth).
 Dec. 12. Lantern lecture.—Aerial Photographic Mapping (at Brighton).

1943.

- Jan. 16. "Some Aspects of Pre-Stressing Concrete by the Freyssinet Methods," by A. Kirkwood Dodds.

YORKSHIRE ASSOCIATION.

1942.

- Oct. 17. Joint Meeting with the local branch of the Institution of Structural Engineers. "Bomb Damage", by William Morris, M. Inst. C.E. (at Leeds).
 Nov. 7. Meeting at Leeds (subject to be announced).
 Dec. 5. Meeting at Sheffield (subject to be announced).

REPORTS.

Birmingham and District Association.

On Friday, 15 May, Students of the Association, with Students of the local branch of the Institution of Municipal and County Engineers, visited the Coleshill and Minworth Grieve works of the Birmingham, Tame and Rea District Drainage Board. The Thomas Hawksley Lecture on "A Century of Tunnelling" was repeated at a joint meeting with the Midland Branch of the Institution of Mechanical Engineers on Friday, 22 May.

Newcastle-upon-Tyne and District Association.

On Saturday, 23 May, a Joint Meeting was held with the North-Eastern branch of the Institution of Municipal and County Engineers, including a visit to the reconstruction of Wylam bridge, after which Mr. Percy Parr B.Sc. Tech., M. Inst. C.E., gave details of the design, construction and partial cracking and deformities of the arch of the Ouseburn culvert and on Saturday, 4 August, a joint visit was paid to Messrs. Rank's new mill, silos, deep-water quay, etc., in course of construction at Gateshead

On Friday, 26 June, a visit was paid to the new North-West quay and new Riverside quay (in course of construction) at Tyne Dock.

Southern Association.

The Annual General Meeting was held on Friday, 10 July, and was followed by a Paper on "Post-War Planning and Reconstruction", by Mr. H. J. B. Manzoni, C.B.E., M. Inst. C.E.

Yorkshire Association.

The Annual General Meeting was held at Sheffield on Saturday, 6 June, and was followed by an Address on "The Aesthetics of Bridges", by Professor C. E. Inglis, President. On Saturday, 4 July, at Leeds, Mr. K. L. Forster, M. Inst. C.E., read a Paper on "The Development of Emergency Sources of Water-Supply" and a visit was paid to the site of an installation.

ROAD ENGINEERING SECTION MEETING.

Tuesday, 2 June 1942.

Sir FREDERICK CHARLES COOK, C.B., D.S.O., M.C.,
Chairman of the Section, in the Chair.

The following Paper was read and discussed.

Road Paper No. 6.

"Earthwork in Embankments."

By ROBERT MEREDYDD WYNNE-EDWARDS, D.S.O., M.C., M.A.,
M. Inst. C.E.

(Abstract.) †

Usually a low embankment presents few difficulties of design and construction; but if the bank is to be fairly high, it is necessary to investigate the properties of the soil upon which it is to be built and the nature and quantity of the materials available for building. It must be known whether the foundations are rock, non-cohesive soils, cohesive soils, or, as is frequently the case in valleys, alternating layers of cohesive and non-cohesive soils overlying each other; how the various materials are likely

† Copies of the full Paper, with a report of the Discussion, may be obtained upon application to the Secretary.

to behave under load ; and also how the materials available for building the embankments are likely to behave during the construction period and after.

The Author discusses the properties of cohesive and non-cohesive soils and the method of investigation by test-pits and borings, to amplify the information afforded by the 6-inch Geological Survey map of the district. The most important facts to be found are (a) the shear strength, which tells whether the clay is strong or weak and controls to a large extent the height and design of the embankment ; and (b) the moisture-content and the liquid limit. The extreme cases of high and low liquid limit are considered in some detail.

The two major aspects to be considered in design are failure by slip and by settlement. The Author describes methods of increasing the stability of a bank if the factor of safety is found to be too low. He also discusses the control of bank building and the problem of proper compaction, and enumerates the chief varieties of plant for use in construction, including cableways ; tractors and scrapers ; tipping lorries, dumpers, and track-laying tipping-wagons ; 4-foot 8½-inch-gauge tipping-wagons and locomotives ; and Jubilee track wagons and locomotives.

The following speakers participated in the discussion :—Sir Jonathan Davidson, Messrs. A. W. Skempton, H. Q. Golder, R. Glossop, A. C. Whiffin, H. G. Lloyd, Walter T. Dunn, A. H. Toms, E. E. H. Bate, G. E. Scott, W. J. Sinclair ; and the Chairman.

CONFERENCE ON

“ Civil Engineers and the Building Industry.”

25 August 1942.

Professor CHARLES EDWARD INGLIS, O.B.E., M.A., LL.D.,
F.R.S., President, in the Chair.

(Abstract.)†

The Chairman set forth briefly the objects and scope of the Conference and said that a number of distinguished speakers had been invited to express their views, to point out defects in existing organizations of the building industry, and to indicate how the many interests concerned could be harmonized. The actual solution of the problems would form the subject matter of further meetings which were to follow.

† A full report of the Conference may be obtained upon application to the Secretary.

The Right Hon. Lord Portal, Minister of Works and Planning, said that the Ministry hoped to get the unanimous counsel of all sections of the industry to advise them. If the necessary good feeling and unanimity could be established it would add enormously to the strength of the industry after the war. There would have to be a balanced programme in order to abolish casual labour and ensure continuity of employment, and it would be the duty of all concerned, civil engineers, contractors, architects, and surveyors, to formulate a plan for the organization of the building industry in such a way that it would live in terms of the new era which was bound to come in this country.

Mr. W. H. Ansell, President of the Royal Institute of British Architects, observed that the most important consideration was not the prosperity of the industry as such, but to ensure the greatest national benefit. Prosperity would follow. There were differences between engineering and building, and to endeavour to force them into the same mould would be a disservice to both. It was better to recognize the true values of each and then to encourage a scheme which would foster them. Houses would have to be built quickly after the war, but speed of erection should not be allowed to outweigh quality of work in design and construction, and over-standardization should be avoided. Three things were essential: good design, good material, and good craftsmanship.

Mr. R. Coppock, General Secretary, National Federation of Building Trades Operatives, said that he wished to ask for the co-operation of The Institution, and that its members should become "mixers" in the industry. Engineers had been more interested in scientific matters than in the human beings who were working on their projects and he hoped that they would develop that human faculty which was so essential if the great industry which they all represented was to deal with the problems that faced it. The energies of all would be required. Without the navy the engineer was of no use, and they should be brought together and their activities correlated. The Institution could play an important part in the remoulding and reorientation of the building industry, and the energy, science, knowledge, and ability of civil engineers would be wanted throughout the Empire.

Mr. Thomas Howarth, President National Federation of Building Trades Employers, thought that in all such discussions personality should be of paramount importance. He did not want the post-war world to be built of poured concrete and steel, but of stone and bricks, wood, steel, and glass, which would express a sense of design and humanism. Craftsmen should be educated in the technical schools. The new ideal of the industry was that everyone in it should be an educated person, not only from the technical point of view but also in understanding of what building really was. Builders wished to "fit in" the world to come in such a way that they could co-operate with every section of society. They wanted to feel that they and the operatives were given a fair deal, and they would

give a fair deal in return. Common sense was needed in dealing with the difficulties of "wet time" and "casualization, but nobody would ever be able to design something that would fit in with the weather of this country.

Mr. H. T. Holloway, President, Federation of Civil Engineering Contractors, said that he proposed to deal with one or two of the practical questions raised by the Conference. His Federation had expressed the very definite view that the civil engineering and the building industries were fundamentally different and separate; and he presented some of the reasons for that opinion. There should, however, be the utmost possible measure of collaboration between them, so that they might speak with one voice. As an example of co-operation, he stated that the two industries had recently agreed to run "holidays with pay" as one scheme for both, and had set up a joint board of management. During the war their co-operation had been very close indeed, and they had formed a joint uniformity board to unify wages on big Government contracts. The aim and policy of the employers was the fullest adoption of collective bargaining, joint agreement with the trade unions on wages and conditions, and the settlement of disputes by conciliation. He also discussed briefly conditions of contract, competitive tendering, and the practice of including in tenders items for "nominated sub-contractors and professional sums"; the problem of unemployment was an evil that had to be tackled and he hoped that steps would be taken to deal with it.

Mr. J. W. Stephenson, President National Federation of Building Trades Operatives, felt that the calling of the Conference was an admission that engineers recognized that they had been divorced from the building industry. He believed that the future would prove a challenge to all professional institutions of the country. The industry had to approach the big tasks ahead as an organized body, and public opinion and public need would demand that many of the existing barriers should be broken down. The primary duty of the professional bodies was to effect the closest possible co-ordination among themselves, so that they could play their part in post-war construction as a properly balanced unit. We were moving into a new era in which the operatives would not be content to be treated as people who stood at the gate; they regarded themselves as partners in the industry. Liaison was not sufficient, and what was wanted was a living unity. He looked forward with interest to the future and to the part that engineers would play; but the industry could not march as a divided force, and if the professional bodies were not prepared to give a lead he was afraid that they would be subject to types of control which hitherto they had tried to avoid.

Col. C. M. Norrie, observed that in the economic field all suffered from the same thing—the extremes of control and interference which had been deemed necessary or advisable in wartime. If, in the post-war period, the methods of control could be simplified, it would be

greatly to the benefit of the industry. He thought also that more realistic use should be made of the representative elements of the industry in the administrative sphere. Since 1919 the general trend in the control of civil engineering contracts had been towards a lowering of the status of the engineer as judge and interpreter of conditions. In some cases the engineer's advice regarding terms of contracts had been ignored and many of his powers had been transferred to a Minister of State, generally with small indication as to how they were to be exercised. Engineers and contractors had been kept apart by such contract conditions at the very time when unity of purpose should have been encouraged and economy fostered through collaboration. In the direction of much administrative policy affecting his own work the engineer was little more than an adviser, and the irony of the position was that we were engaged in what was mainly an engineer's war of movement and adaptability. The need for engineering representation and responsibility in the formulation of policy was especially necessary in colonial development, since the pioneer work in nearly all spheres was initially of an engineering nature.

The Chairman, in closing the Conference, pointed out that it was to be followed by a number of Discussion Meetings, the first of which would take place on the 15th September, when Mr. George Hicks, M.P., Parliamentary Secretary to the Ministry of Works and Planning, would be the leading speaker. That meeting would be followed by four others at monthly intervals.

SYNOPSIS OF A PAPER FOR DISCUSSION.

The following Paper will be brought forward for discussion on the date indicated in the margin of the synopsis, and will be published, with reports of the oral and written discussions upon it, in the Journal. Members desiring to take part in the consideration of the Paper should apply for advance copies, which will be forwarded as soon as they are ready. Applications for proofs should be made on postcards.

"Hydro-Electric Development—Some Economic Aspects."

- By JOHN KENNETH HUNTER, B.Sc. (Eng.), and
REGINALD WILLIAM MOUNTAIN, B.Sc. (Eng.), MM. Inst. C.E.

The Paper deals with the way in which some of the economic problems associated with the development of water-power have been altered in recent years as the result of the widespread development of large interconnected systems. From the analyses made, certain broad principles are deduced, which may be of value when examining proposals for hydro-electric development.

From a consideration of the cost of steam power, an attempt is made

Date of
Discussion
1/12/42

to define a standard of comparison, and the conditions under which the value of a hydro-electric station may be enhanced by a reduction in its design load factor are discussed.

Reference is made to some of the economic problems associated with pumped storage plants, with special reference to their influences on interconnected steam stations.

ENGINEERING ABSTRACTS.

Copies of the *Zeitschrift des Vereines deutscher Ingenieure* from 26 August 1939, to 27 December 1941 (Volumes 83, 84, and 85) have been received recently by The Institution. The following abstracts of some of the articles have been prepared:

The Mechanical Properties of High-Strength Plastics : A. THUM and H. R. JACOBI (**Ver. deu. Ing.*, vol. 83, 1044-1048, 16 Sept. 1939). The use of plastics in the construction of aircraft and power vehicles is now extensive; but hitherto little has been known of their mechanical properties, which must include high strength and low brittleness, and depend largely upon the composition of the material, chiefly the resin-content, usually 30-50 per cent. The Authors have therefore carried out an investigation of these properties, especially the endurance strength of fabric-laminated and type T3 plastics and of paper-laminated and type Z3 plastics.

The minimum mechanical properties are :

	Young's modulus (tons per sq. in.).	Compressive strength (lb. per sq. in.).	Tensile strength (lb. per sq. in.).	Bending strength (lb. per sq. in.).	Impact bending strength. (foot-lb. per sq. in.).
Type T3	250-570	17,000	7,000	11,400 *	1,670
Laminated fabric	440-570	28,500	11,400	14,000	2,010
Type Z3	500-820	22,700	11,400	17,000	1,020
Laminated paper	500-700	21,300	17,000	18,500	1,670

The creep properties depend upon the special elastic-plastic structure of the material, and the tensile strength : elongation curves vary considerably with the temperature and the rate and period of loading. On the other hand, the elastic modulus varies inversely with the period of loading. The alteration of the tenacity with the rate of loading follows from the dependence of the resistance to deformation of the plastic constituent of the material upon the rate of deformation. Hooke's law is not followed by these materials : one speaks of an "elastic hysteresis" of resins, in con-

* An asterisk indicates that the article is illustrated.

trast to the "plastic hysteresis" of metals, in which the hysteresis is essentially a result of crystal slip. Type T3 plastics have a lower endurance strength than type Z3, and both are only a little above that of a pure plastic. The ratio endurance strength : bending strength is about 0.25–0.3; the notch sensitiveness is relatively low. The appearance of fractures varies with the resin-content and the type of the material. Fractures due to bending stresses are brittle and easily distinguishable from those caused by a single blow. In torsional endurance tests, shallow specimens always crack along the laminations.

Behaviour of Annular Rubber Springs under Tensile and Alternating Stress : F. GÖBEL (**Ver. deu. Ing.*, 85, 631–635, 19 July 1941).

—(1) The use of polar equivalence diagrams for the investigation of flexible mountings in the tensile test, though in general use, is laborious and expensive. For aero-engines the displacement f does not usually exceed 1 cm. axially and 0.5 cm. radially. In these circumstances $P = 2\pi f G h / \log_e(d_2/d_1)$, where P denotes the axial load in kilograms, h, d_1 and d_2 denote the dimensions of the annulus in centimetres, and G [kg. per square centimetre] denotes a shear modulus. The latter depends on f as well as on the rubber and is approximately equal to 450 divided by the "softness number," that is, the penetration (in 1/100 mm.) of a 10-mm. steel ball into a 6-mm. thick rubber sheet in 10 sec. when loaded with 1 kg. with 50 gm. prior load. For annular mountings with equal shear stress $2fG/(d_2 - d_1)$, equal springing is given by $P = 2\pi f h_2 G / (1 - h_2/h_1)$. Durability depends on size, design, rubber type, bonding; best values of shear stress to onset of rupture are 66 and 34 kg. per square centimetre ± 30 per cent. for annular and washer mountings respectively; bonding is rather better with light alloy than with steel. At 85° C., the temperature which these mountings usually reach, springing is reduced by about 2 per cent. and durability by about 50 per cent.; at about 230° C. stickiness occurs, and by 250° C. they are useless. (2) Alternating stress causes rupture or stickiness at a point and failure follows progressively, not as in metals; the Author therefore defines useful life as that until the springing value has dropped by 10 per cent. More than 30 million reversals are needed to give the fatigue stress, in comparison with 10 million for steel, and in practice large mountings have a durability greater than smaller ones. Internal damping sets up a steady temperature in $\frac{1}{2}$ –2 hr. and failure is eventually due to local heating. In *post mortems* local or plane stickiness is an indication of fatigue failure.

Except in poorly bonded mountings, fracture shows that the stress-concentration is highest at a little distance from the metal cylinder. In annular springs fatigue fracture occurs on the pressure side, the rubber being frayed and sticky; the other side shows a normal tensile break. The fatigue fracture of flat mountings is velvety and mat grey; its surface is almost flat, and sticky; the final break is markedly fissured.

Optical Measurement of Length in Land Mapping : W. SCHNEIDER (**Ver. deu. Ing.*, 85, 233-239 ; 8 March 1941).—For estimated accuracy of 1/50,000, 1/5,000, and 1/500 to 1/100, required in triangulation, cataster survey, and mapping, respectively, the Author examines how far optical methods can replace direct methods. In optical measurement the relative errors are given by $\left(\frac{\Delta s}{s}\right)^2 = \left(\frac{\Delta b}{b}\right)^2 + \left(\frac{\Delta \gamma}{\gamma}\right)^2 + \left(\frac{\Delta R^2}{4R^2/\pi^2}\right)^2$. To ensure overall accuracy of 1/5,000, if $s = 100$ m., $b = 1$ m., $\gamma = 1/100 = 2062.6$ seconds, demands $\Delta b = 0.1$ mm., $\Delta R = 0.57$ degree and $\Delta \gamma = 0.2$ second. Whilst the first and second are not difficult to attain, $\Delta \gamma = 0.2$ second demands the very best technique. To minimize refraction a horizontal base is desirable; shimmer can be combated by repeated observations, especially at different atmospheric states, for example, morning and evening. The fundamental equation of range-finding, $s = b \tan \gamma$, becomes for a horizontal base $s = b \cot \gamma' \cos \beta$, reducing to $\cot \gamma' \cos \beta = 100$; similarly for a vertical base $\cot \gamma \cos^2 \beta = 100$, giving $s = 100b$ by suitable adjustment (a self-reducing tachymeter). When a larger auxiliary base is used its length should be \sqrt{sb} for the highest accuracy. For the double-image method the half-wedge addition to the telescope objective is recommended; accuracy is substantially independent of working range, and parallax and oscillation of the lath in its plane of graduation do not affect the results. Optical characteristics are tabulated for various theodolite types, with special reference to the accuracy attainable. In general the method cannot attain the highest accuracy (1 mm./100 m.) but below (1 cm./100 m.) it is quicker and easier, especially in hilly, broken, or uneven country or with obstacles or traffic. The ground does not need to be walked over. The method is adversely affected by bad atmospheric conditions—flicker, mist, refraction—but measures can be taken to combat these.

Measurements at Reservoir Embankments : J. EHRENBURG (**Ver. deu. Ing.* 84, 495-500 ; 13 July 1940).—The Author describes various methods and apparatus for measuring the internal stresses and other conditions relating to reservoir and similar embankments. Internal settlement can be ascertained by means of a system of telescopic piping with large flanges which move with the surrounding soil. Alternatively, if an inspection gallery is available, a method based on the relative water-levels in a U-tube may be used. Internal pressure may be measured acoustically by means of special boxes buried in the embankment and containing a wire under tension, which varies with changes of the pressure. The wire is vibrated by plucking it magnetically, and the resulting musical note is received by microphone. The operator compares the note with that of a similar calibrated wire; if the two tensions are different, a warbling note ensues. The tension of the calibrated wire is adjusted until a steady note is obtained, when both wires are in unison. The corresponding

pressure is obtained from a calibration curve. The vibrations can also be compared optically by means of light-curves. These systems can be used for horizontal as well as vertical pressures. Another method is based on electro-magnetic principles. Pressure-variations on the buried measuring-box alter the clearance between the two poles of a magnet, thus changing the strength of the magnetic field, which can be converted to a pressure-scale. The layout for installing these apparatus is described. The above methods measure the pressure of the soil and pore-water together. Since the stability of the embankment depends on soil-pressure alone, it is necessary to deduct the internal water-pressure. This latter pressure may be measured separately by means of small containers with open tops and filled with sand with a gravel underlayer; these containers are buried in the embankment and connected to pressure-gauges in the inspection gallery.

An Easily Erected Gantry for Road Transport : PETER WEINHEIMER (**Ver. deu. Ing.*, vol. 85, 423-425; 3 May 1940). A detailed description is given of a gantry capable of rapid adaptation for road transport. The model described has a lifting power of 20 tons, the working span and height being respectively 33 feet and 26.5 feet. The superstructure is of welded tubular construction. Each of the duplex vertical supports is carried on a swivelled chassis which permits the ready adjustment of the wheels from transport to working position and vice versa. Each half of the support has a knee-joint at half-height, permitting the expansion of the leg to form a flattened rhombus when the gantry is lowered for transport (travelling height $7\frac{1}{4}$ feet). The pull exerted by the cables is equalized by lever bars between the knee joint and the main struts. The gantry can be erected or prepared for transport by a crew of four men in 4 minutes; it can also be carried on certain types of railway float. For road transport it is usually towed by a lorry at normal speeds: if these exceed 15.5 miles per hour the wheels should have pneumatic tires, but solid rubber tires can be used at lower speeds.

The Development of Bridge Welding during the Past Three Years : KURT BRÜCKNER (**Ver. deu. Ing.*, vol. 85, 460-462; 17 May 1941). The standard requirements of the German National Railways and of the motor roads for welded steel structures have been somewhat modified as a result of investigations into the failure of two welded bridges in Germany in 1936 and 1938. The use of Thomas (basic) steel is now permitted only in plate not exceeding 0.8 inch thick and in angles or flanges not more than 1 inch thick, since it is recognized that steel of riveting quality may have too high a carbon- or phosphorus-content to be fit for use in welded structures, and that dangerously large inclusions may occur in thick plate or sections. Requirements regarding testing, maximum thickness, and heat-treatment are tabulated for basic and open-hearth steels. Some further modification is considered desirable, since the ores now available

are best suited to the production of basic steel, and reference is made to a recently developed steel of this type approximating in properties to the former steel St.48 but having a maximum carbon-content of 0.25 per cent. In general, normalization is obligatory for plate 1.2 inch thick or more, and for sections and flanges 1.6 inch thick or more; it may be waived by agreement for sections and flanges ranging from 1.2 inch to 1.6 inch thick, and may be omitted by permission if evidence of satisfactory properties is produced. Thicknesses exceeding 2 inches are prohibited for the present. Permissible stresses have been slightly reduced for thick sections. Flanged girders more than 0.8 inch thick must be laminated, or specially rolled sections must be used. In regard to welding practice, gas-welding is said to predominate, but automatic electric welding is being increasingly used on long welds and in shop-built work. The buckling stress of bridge welds has been investigated by G. Bierett, who makes certain recommendations regarding welded butt joints. In conclusion reference is made to the increased cost of welded as compared with riveted structures, especially in view of the higher standard of quality for the former and of the additional tests required. It is stated that owing to war conditions riveted construction has tended to displace welding, but this phase is regarded as only temporary.

Output in Road Construction Increased by Investigating Causes of Lowered Efficiency : G. GARBOTZ and J. SCHLUMS (**Ver. deu. Ing.*, vol. 85, 741-746; 6 Sept. 1941). Efficiency studies of concrete and bituminous road construction carried out on motor road and trunk road sites in Germany from 1933 onwards are reviewed and epitomized in a series of graphical summaries. The most important conclusions are as follows: *Concrete*.—Single-course construction should be more extensively used, and half-width is preferable to whole-width construction. Output can be increased by using either a very dry mix, which is consolidated by vibration, or a wet mix finished by screeding. Mixing is the key operation, with which transport, batching, placing and finishing must be correlated. Mixing times may be reduced considerably by using free-fall mixers discharging into a trough, in combination with continuous batching. American experience suggests that travelling shelters for protecting green concrete are unnecessary. Output would probably be increased by using ready-mixed concrete. *Bituminous surfacings*.—Increased use should be made of band conveyors in handling materials. Proportioning by weight and premixing should be adopted on main road sites, as on the motor roads. As in concrete construction, the mixer is the key unit in the operating cycle. Recording pyrometers should be installed to prevent overheating of binder and aggregates. Mixing time can be minimized by selecting the optimum speed for the mixing-shaft. Dual-shaft pugmill mixers are preferred. The effectiveness of mixing should be checked by the safranin test. For multiple-group operations a single large mixer is more economical

than several smaller units. A sufficient number of transport units and rollers must be provided. The design of finishing machinery is considered to require drastic modifications.

Course-Keeping in Motor Vehicles as affected by Lateral Wind-Pressure : L. HUBER (**Ver. deu. Ing.*, vol. 84, 705-712; 21 Sept. 1940). Danger from sudden lateral gusts is most likely in closed vehicles, where side-winds are first perceived through their effect on the direction of the vehicle after an interval of about 1 second (approximately equal to the average perception and reaction period). The behaviour of the vehicle during this interval has been studied by tests on a moving track with unsteered models, wind-channel measurements of the lateral force exerted, analyses of the various sideway forces operating on the vehicle on a non-skid surface, observations on the stability of models and of racing vehicles under centrifugal force, and investigations of the influence of body design and load-distribution. Streamlined vehicles are less stable than ordinary cars under lateral wind-pressure; the most stable form of vehicle has the centre of gravity well forward, whilst lateral forces are transmitted towards the rear by a pair of slotted fins. The design of the body should aim at concentrating lateral wind-pressure between the centre of gravity and the centre of the vehicle. A description is given of a "side-wind-proof" car designed on these principles: it is stated that the results of road trials were satisfactory.

Bridge Structures on the National Motor Roads : K. SCHAECHTERLE (**Ver. deu. Ing.*, vol. 85, 747-748; 6 Sept. 1941). The construction of the German motor road system without intersections at road-level has necessitated an unusually large number of bridge structures, varying widely in design and material, but aimed at securing the maximum harmony of effect. Six examples are illustrated. Standard designs have been developed for the smaller structures (arched culverts, underpasses, and the shorter overpasses), though individual designs are often used where local materials can be effectively introduced. The treatment of the major structures depends upon local conditions, and is based in each case on a full investigation of technical and economic considerations.

Shop Tests on Self-Locking Compensating Gears for Motor Vehicles : F. G. ALTMANN and G. HEIMANN (**Ver. deu. Ing.*, vol. 85, 749-754; Sept. 1941). Self-locking compensating drives are at present fitted mainly to military vehicles, but their use is likely to become more general. The device largely eliminates "racing" when one of the driving-wheels fails to grip the ground satisfactorily. The locking power of two compensating drives—a curved-race drive with rocker bearings, and a helical drive—has been compared with that of an ordinary differential (bevel) drive in two testing assemblies, in which measurements were made of the

torque on the transmission shafts, of the power transmitted from engine to compensating drive and from drive and brakes, and of the power absorbed in transmission. The results are compared in a series of diagrams where the ideal power-distribution is also shown : the conditions include equal gripping of driving-wheels on straight and on curved road sections, and unequal gripping during starting and during the run. The superiority of the helical drive is demonstrated throughout.

Experience of the German State Railways with Home-Produced Materials.

I. Metals : W. HÖFINGHOFF (**Ver. deu. Ing.*, vol. 84, 465-471 ; 6 July 1940). The Author describes some of the methods adopted by the German State Railways, during the "Four-year-plan," to reduce to the minimum the consumption of those raw materials which could only be obtained from abroad, at the cost of foreign currency. He is mainly concerned with the details of locomotive and carriage construction. Typical of the expedients described are the use of steel for locomotive parts formerly made of copper, and the employment of alloy steels based on manganese and silicon instead of imported chromium, molybdenum, tungsten, and vanadium, for boiler-plates and other high-duty components.

By using steel or cast iron in place of copper, brass, and bronze large quantities of the latter metals were saved : many details, such as valves and axle bearings, were redesigned in cast iron or steel, using the smallest possible quantities of bronze, white metal, etc., in the form of bushes or facings. The extended employment of roller-bearings in locomotive and carriage construction also contributed to the desired result.

Attempts were made with varying degrees of success, to make greater use of aluminium alloys (chiefly with magnesium, or magnesium and silicon) for steam-, water-, air-, and oil-pipes ; and copper is practically no longer used for any of these purposes in locomotive building.

Water-tanks were also evolved, making use of surface-protected aluminium alloys, which have been found to withstand the injurious effects of frequently changing water-supplies. The design of a satisfactory tap in aluminium alloy presented special difficulties, and the means whereby they were overcome are described.

Alloys of magnesium and also of zinc have been tried for various purposes, but with limited success ; chiefly owing to the difficulty of finding a satisfactory surface treatment for the former and the poor behaviour of the latter under the influence of temperature.

Experiments with both are still in progress.

II. Non-Metals (pp. 581-585 ; 10 Aug. 1940). The Author indicates an extensive range of locomotive and carriage fitments which are now being made of artificial substances such as wood-fibre board (with or without veneer) and various kinds of synthetic resins or plastics.

By the use of wood-fibre board (made from saw-dust and saw-mill waste) for ceilings, floors, and wall-panels of passenger-coaches, considerable quantities of sawn oak, elm, teak, pine, and fir are saved.

Among the articles which it was found possible to make from one or another of the numerous plastics now available were heating regulators, blind-cases, lamp-sockets, brackets, lighting fittings of all kinds (including gas lighting) clothes-hooks, lavatory fittings, door and cupboard handles and fastenings (reinforced where necessary with a steel core), water-cisterns, window-frames, etc.; many of the objects are illustrated. Most of them were formerly made from various imported light metals, and the resulting aggregate saving to the State of foreign currency was considerable. In many cases the result of the change was positively advantageous—especially where the corrosive effect of moisture had previously to be reckoned with.

High-duty plastics are also being successfully employed as bearing- and sliding-surfaces in locomotive work.

In addition the uses of synthetic rubber (for brake- and steam-heating hose), artificial leather, linoleum, and a new scratch-proof fabric for the treatment of surfaces in passenger rolling-stock are discussed.

Experiments with Welded Rails : OTTO GRAF (**Ver. deu. Ing.*, 1250-1253; 2 Dec. 1939). Experiments are described to determine the ultimate strength under repeated bending stresses of both gas and flash-butt welded rail joints, and also of new and second-hand whole rails, of similar types. Rails from various sources were supported on bearings 100 centimetres apart and repeatedly loaded at the rate of 250 repetitions per minute up to 2 millions, the range of the stress-variation in the outermost fibres being increased by increments of 0.5 kilogram per square millimetre until failure occurred; the results are tabulated.

Micro-photographs show alterations of the metallic structure and variations in the Brinell hardness resulting from the welding process near a typical joint.

The effect of total—in comparison with partial—removal of the excess weld-metal at a joint was investigated. Experiments were also made to determine the value of side plates or wings edge-welded in a horizontal position to the flanges of a flat-bottomed rail joint for additional strength, and it was concluded that they were unnecessary if the weld were properly executed.

In general the tests are held to show that it is now possible to produce a welded joint of such strength as to justify the adoption of rail welding on a large scale. To what extent gas- or flash-butt welding should be employed depends upon costs, facilities for occupation of the track, and last, but not least, the dependability of the individual welder. Probably gas-welding is preferable for in situ work, and the flash-butt process for shop work.

AERODROME ABSTRACTS.*

Compiled by the Department of Scientific and Industrial Research
(Road Research Laboratory) and issued in Collaboration with the
Air Ministry.

*The Road Research Laboratory and the Ministry of War Transport jointly compile
"Road Abstracts" to which reference is made.*

1942, Vol. I, No. 4.

Abstracts Nos. 64-75

Note.—The abstracts purport to be fair summaries of the original literature, but no responsibility can be accepted by the Department of Scientific and Industrial Research for the accuracy of authors' statements or for their opinions.

Publication—Alternate months. A subject- and name-index will be issued annually.

64. Location and Use of "Flight Strips" : S. S. HANKS : *Rds and Str.*, 1942, 85 (4), 67-8, 70, 72. A flight strip is an area for the landing and taking off of aeroplanes, adjacent to a public road and maintained as part of the right-of-way or roadside development area. The Defence Highway Act of 1941 authorizes the U.S. COMMISSIONER OF PUBLIC ROADS, in co-operation with the U.S. ARMY AIR CORPS, to study and carry on the construction of flight strips. The building will be done by the U.S. PUBLIC ROADS ADMINISTRATION with technical advice and instructions as to number, locality, and nature from the U.S. ARMY AIR FORCES. The military use of flight strips will be to form part of a network of landing areas, to allow for dispersal of aircraft and to increase air traffic facilities. For civil aviation in future they will serve for auxiliary commercial lines, for the probable increase in private flying and for planes of all kinds forced down in emergency. For military use the runway on the strip should be

at least 150 ft. wide, 3,000 ft. long for pursuit planes and 4,000 ft. for other types. The runway should be smooth, with a gradient of not more than 1 in 100, and it must have adequate bearing capacity. It may be surfaced or covered with heavy grass turf, with or without soil stabilization. In the original specifications the probable maximum load for military planes was estimated at 160,000 lb. divided between two wheels about 30 ft. apart. It is believed that present designs will involve up to the spring of 1944 gross loads of 120,000 lb., static wheel loads of 60,000 lb., tyre inflations of 70 lb., impact factors of 25 per cent., with a design stress requirement of 583 lb./sq. in. and a minimum safety factor of 1.20. There should be at each end of the runway a trapezoidal area 2 miles long, not less than 300 ft. wide at the boundary of the flight strip area and 4,000 ft. at the other end, within which no obstacle is allowed that is high enough to obstruct an angle of glide of 1 in 40. In some cases 1 in 30 may have to suffice. Within the strip no obstruction or building should be permitted within 150 ft. of the centre line of the runway. While the number of flight strips constructed will depend on strategic dispositions, in general each squadron of 12 to 25 machines will require one flight strip, with one extra for every three squadrons, i.e. 4 flight strips to each "group."

(*Erratum*.—A letter by the Author has since appeared in *Rds and Str.*, 1942, 85 (5), 48, in which he corrects the value of 583 lb./sq. in. given for the design stress to 97.5 lb./sq. in. or, in round figures, 100 lb./sq. in.)

65. **Airports in National Defence** : B. E. GRAY : *Milit. Engr.*, Wash., 1941, 33 (190) ; Reprinted by the Asphalt Institute, pp. 5. The necessity is emphasized for the speedy building in the U.S.A. of thousands of aerodromes, not all of which need to be of a permanent character. The following factors influencing the design and construction of runways are discussed :—volume of traffic and type of aircraft using the runways, loads to be borne by the surfacing, thickness of surfacing required, and types of subgrade. It has been found in the U.S.A. that when an aerodrome has been adequately drained and has a layer of pervious subgrade there have been no failures of a surface course 4 in. or more in thickness. Bituminous surfacings for runways differ from road surfacings in that a softer binder is desirable for runways to make up for lack of traffic and that the surface texture of a runway should always be of a sandy nature so that the aircraft will not be damaged by particles picked up by propeller blast. Four types of bituminous surfacings are described :—surface treatment and mixed-in-place types for the lighter-duty aerodromes and penetration macadam and plant-mix types for heavy-duty surfacings. It is suggested that the maintenance of aerodromes should be taken over by the State Highway Departments.

66. **Standard Runway Marking** : ANON. : *Aero Digest*, 1941, 39 (2),

58. The method is described that the U.S. CIVIL AERONAUTICS ADMINISTRATION recommends for the marking of aerodrome runways. Each runway is numbered by the first two figures, correct to the nearest tens digit, of the reciprocal of its magnetic compass bearing, e.g. a runway lying north and south would have 36 on the south end and 18 on the north end ; thus the number of the runway on which he was to land would enable the pilot to set his course correctly for it while approaching the aerodrome. Details and illustrations are given of the design for numerals 50 ft. by 25 ft., of the marking of runways (edges and centre-lines) and taxi strips with lines of paint, and of warning marks near the end of the runways. Washington National Airport carries all the markings recommended, in paint in which small glass prisms have been sprayed to aid visibility at night.

67. **Investigation of Soil Conditions in Airport Construction :** W. S. HOUSEL : *University of Michigan, Department of Civil Engineering* : Ann Arbor, Michigan, 1941 (The University), 9 in. by 6 in., pp. 26, fig. 12, unpriced. In planning and developing an aerodrome site the nature and behaviour of the local soil is an important factor in the first costs incurred and in the production of satisfactory results, especially in surfaced areas. The knowledge of soil mechanics gained in recent years, which has made it possible to use soil as an engineering material with much greater security, is available in two ways. Soil survey maps and bulletins prepared by the Soil Survey Division of the U.S. BUREAU OF CHEMISTRY AND SOILS describe the general character of the soil, usually covering the whole of a county. A typical soil map is illustrated, and examples are given of its usefulness. A map of the U.S.A. shows the areas in which either detailed or reconnaissance surveys have been made. All usable areas will probably be covered eventually. This information gives help in preliminary planning and eliminates many serious mistakes. In the second place, special investigations and tests give information on specific materials and aid in designing and constructing specific jobs. *Soil classification.* (1) Soil materials, as distinct from soils, are the solid portion of the soil removed from its natural environment. They are classified on the basis of texture or particle size distribution determined by mechanical analysis. The groups adopted by the U.S. BUREAU OF CHEMISTRY AND SOILS are clay, silt, four sizes of sand and two sizes of gravel. Clay and silt are spoken of as binder, sand and fine gravel as fine aggregate, and gravel as coarse aggregate. Fine aggregate and binder together may be referred to as soil mortar ; the importance of soil mortar and the fact that many soils contain little or no gravel leads to a classification by texture into 11 types, based on the proportions present of the three primary types, sand, silt and clay. At one extreme are granular materials (sands), which have no cohesion and little capillarity, are highly permeable and mechanically very stable when confined ; at the other are cohesive materials (clays), with high capillarity and low permeability. Silts, being intermediate, have not the advantage

of either extreme, and if present in a subgrade exposed to moisture, may be a source of danger. (2) Soil in situ is such a complex material with such a wide range of behaviour depending on environment, that in practice provision must be made for an unlimited number of soil types. The basis of the system adopted by the U.S. BUREAU OF CHEMISTRY AND SOILS is the soil profile descending from the weathered surface, leached by percolating waters, through a zone where the constituents leached from it have been deposited, to the parent material which is either transported or formed by weathering of the bedrock, and the bedrock itself. Six types of classification are used, dividing soils according to the texture of the surface layer; the parent material, environment and climate; special features such as drainage or deposition within the same group of environment; widespread characteristics of environment such as climate, rainfall and temperature; inorganic colloidal composition, connected with widespread types of weathering due to temperature; and chemical composition depending on widespread differences in rainfall and humidity. *Soil tests.* The principal properties on which information is required are the bearing capacity, the change in volume at different moisture contents and the capacity for being drained, depending on permeability and capillarity. In cohesive soils, bearing capacity is a function of shearing resistance, which controls the resistance to lateral displacement under applied load. Diagrams illustrate how the developed pressure that a soil mass can support is equal to four times the cohesive shearing resistance. This can be measured by driving a standard core barrel with a standard blow of a falling weight (penetration method), or by applying loads to a transverse section of the undisturbed soil core obtained by means of the core barrel. In granular soils, bearing capacity depends on internal stability, a function of the mechanical arrangement of the soil particles and the lateral pressure, which tends to confine the loaded element. Diagrams show how to calculate the formula for this function. The significant vertical and lateral pressures can be directly measured by placing the soil specimen, enclosed in a rubber membrane, in a pressure tank, where constant lateral pressure is maintained, and applying vertical loads till failure is reached (stabilometer test). Shearing resistance, known as internal friction in granular materials, is a function of normal pressure. A diagram shows the action of shearing resistance in transmitting pressures through a surfacing or stabilized base. In such a case a test must be made to measure the punching shear. The problem of measuring the capillarity and permeability of soils is not yet fully solved, but drainage problems necessarily vary in different soils, e.g. from heavy clays, where surface drainage has to carry away most of the run-off and sub-drainage may be required to lower the water-table, raised by high capillarity, to well-drained sands where sub-drainage is not needed. *Soil stabilization.* Excessive volume changes in a soil mass may be eliminated by improving the grading in the case of loose granular soils or heavy clays, by compaction in the case of porous soils,

by adding cement to solidify the soil or by adding bitumen to exclude moisture.

68. **New Runways by Soil-Cement** : ANON. : *Aviation*, 1941, 40 (11), 69-70. At the Hatboro aerodrome of the Brewster factory at Johnsville, Pa., three runways, each 100 ft. wide, were constructed with 3,000 ft. of stabilized soil surfacing each. The site required little grading, and after the topsoil had been removed a trough 100 ft. wide and 6 in. deep was excavated for each runway and filled with 7 to 8 in. of sand and gravel from a borrow pit on the land. After initial compaction and levelling, cement (10 per cent. by volume) was spotted in piles over the filling, brushed evenly over the surface, and mixed with the soil by five rotary tillers. Water was added by a pressure distributor and the rotary tillers were again employed. As no expansion joints are used with soil-cement, work proceeded on a 24-hr. basis to avoid the checkerboard appearance that would result from allowing one portion to harden at a time. Compaction was done with sheepsfoot rollers, followed in turn by a scraper, a normal tandem roller, and rollers with smooth pneumatic tires. The edges of the runways were prevented from crumbling by rolling cinders along the edges level with the runway surface. Drainage pipes were laid under the cinders. The construction time was three months.

69. **Omaha's Municipal Airport** : F. S. GILMORE : *Aero Digest*, 1941, 39 (2), 67-8, 71, 227. At Omaha Airport existing runways are being extended and additional runways built. Considerable expansion is planned for the future. While the construction is essentially similar to that previously used (see *Road Abstr.*, 1941, 8, No. 18), some of the specifications are closer, experience has been gained in the maintenance of the runways and further tests have been carried out on the bearing capacity of sub-grades and base courses. According to the present specification, the densified soil sub-base has a uniform thickness of 12 in., placed in two 6-in. layers and compacted to 95 per cent. of the Proctor maximum. All material shall have a liquid limit of less than 45 and a plasticity index of 10 to 20, and soil not conforming to this is replaced or altered by additions. After compaction the formation is shaped to the cross-fall of the runways. The base is 5 in. thick, and consists of sand-gravel and binder soil, in which the total material passing the 40-mesh sieve shall have a plasticity index not exceeding 15. The sand-gravel is washed sand and gravel graded from 100 per cent. passing the 1-in. sieve to 85 to 90 per cent. retained on the 40-mesh sieve. The materials may be mixed in place, but during the present season they have been plant-mixed for the most part. A continuous pugmill mixer is employed, and the proportions of the materials are volumetrically controlled. After compaction with sheepsfoot rollers to the Proctor maximum, the base is dressed and shaped to the contour of the finished surfacing. The hot-mix asphaltic concrete surfacing con-

sists of a $1\frac{1}{2}$ -in. binder course spread at 160 lb./sq. yd., rolled while hot, and covered while hot by a $\frac{1}{2}$ -in. wearing course of sand asphalt spread at 50 lb./sq. yd. The aggregate for the binder course is graded from 4 to 10 per cent. passing the 1-in. and retained on the $\frac{1}{2}$ -in. screen, and the mixture contains 4.5 to 7 per cent. of asphaltic cement of 130 to 180 penetration. The aggregate for the wearing course is graded from 6 to 12 per cent. passing the 200-mesh sieve to 0 to 10 per cent. passing the 4-mesh and retained on the 10-mesh sieve, and the percentage of asphaltic cement is 9 to 15. Runways constructed in and since 1936 are in excellent condition, and maintenance has consisted mainly of rolling with pneumatic-tired rollers on hot days in July and August. Some damage was caused to the wearing surface at the ends of runways by heavy planes in turning with a locked wheel. With time the surface becomes tough enough to resist this, but on one section an asphaltic cement of 85 to 100 penetration solved the difficulty. A light oiled earth apron of temporary type proved unsatisfactory owing to the seepage of water through to unstable subgrade, and will have to be replaced. Since the load-bearing tests made for the original designs, laboratory tests have been made on a larger scale, using a 12-in. layer of subsoil, covered with two 6-in. layers of compacted sub-base soil, a soil-aggregate base course and a 2-in. layer of asphaltic concrete. The bearing capacity of each layer was tested with each of 4 circular steel plates 216 sq. in., 144 sq. in., 72 sq. in., and 36 sq. in. in area. In field tests the same plates were used, with the addition of one 432 sq. in. in area. The plates were fixed in place with plaster cement paste and pressure was applied by means of a hydraulic jack. In both laboratory and field tests, readings were taken at the points of $\frac{1}{8}$ -in. and $\frac{1}{4}$ -in. deformation of the surface. The results of these investigations, taken in conjunction with the performance of surfacings already laid, confirmed the theory of P. HUBBARD and F. C. FIELD that the unit load-supporting value of subgrades and stabilized base courses decreases as the area of loading increases (see *Road Abstr.*, 1942, 9, No. 34) and showed that the design curves proposed by them are conservative, especially for the larger areas of loading.

70. A Short Note on Lisbon Airport : F. DE MELO E CASTRO : *Boletim da Ordem dos Engenheiros*, 1940, (48) ; *Rev. aero.*, 1941, 17 (4), 155-9. Lisbon airport has four runways, arranged in the form of a right-angled isosceles triangle bisected. Each runway is about 1,200 m. (3,937 ft.) long and 250 m. (820 ft.) wide, with a central surfaced strip 164 ft. wide. Drainage is carried to a ditch surrounding the aerodrome, and consists of 3 networks, one for the raised field, one for the surrounding slopes, and one for the runways and buildings. About 130,000 m. (426,517 ft.) of 2.4-in. pipe have already been laid. The central strip has a base of 9.8-in. of stone covered with 7.8 in. of macadam and a 2-in. bituminous surfacing. To make a gradual transition from this strip to the unsurfaced runway shoulders, the outside edge for a width of 5 m. (16.4 ft.) has a thinner

surfacing of the same type. The parking apron between the buildings and the principal runway is surfaced with concrete slabs 32·8 ft. by 16·4 ft., and 5·9 in. thick, laid over 9·8 in. of broken stone. The slabs are made of vibrated concrete containing 300 kg. of cement to the cu.m. (508 lb./cu. yd.).

71. **Concrete on Airfields :** R. A. B. SMITH : *Highw. and Bridges*, 1942, 8 (399), 4, 6 ; (400), 4, 6. This paper discusses the use of concrete in the drainage of aerodromes and aerodrome runways and in the surfacing of runways, taxi strips and aprons. *Drainage.* To drain the grassed areas of an aerodrome it is usually necessary to lay a system of clay or porous concrete pipes leading to larger pipes and thence to ditches. Porous concrete pipes are more efficient than clay pipes of the same size, and therefore cheaper, since fewer will be required. They are also stronger ; with a cover of 12 in. they will resist considerable shock from the impact of landing planes, and if broken they can still function. The trench should be filled with broken stone or gravel of $\frac{1}{2}$ -in. size or more, to within 6 to 9 in. of the surface. Runways may be drained in the same manner, with a larger size of collector pipe. The trenches may be placed 2 ft. from either edge of the runway, in which case the whole surface from the edge to 1 ft. beyond the trench should be covered with coarse stone to a depth of 6 to 9 in. or 12 in. in exceptionally heavy soil. Alternatively the drain may be placed under the slab 6 ft. or more from the edge, and in Canada central drainage for runways is being investigated. *Surfacing.* Concrete surfacing for runways is cheaper than any other permanent surfacing, has a good coefficient of friction in both wet and dry weather and is easily visible at night. The thickness of the slab must be calculated in relation to the bearing capacity of the ground. Although the weight of modern aircraft has rapidly increased, the larger tires with which they are fitted and the increased area of tire pressure neutralize this. $2\frac{1}{2}$ tons/sq. ft. has been adopted as a figure for impact load. Again, a landing aeroplane has a forward motion of more than 60 m.p.h., so that impact load is not likely to exceed the total weight of the machine distributed between the two main wheels : 25 per cent. extra is usually allowed as a precaution. A formula used in the U.S.A. for calculating the thickness is quoted, and as a general rule 8 in. will be sufficient over a hardcore base, 10 in. on a good natural base and 12 in. on poor ground. With reinforcement the first two can be reduced by 2 in. and the third by 3 if the sub-base is prepared. The width of slabs should not exceed 15 ft. when reinforced and 10 ft. when not reinforced. On ground of good bearing capacity reinforcement should be needed only over wide or deep trenches and at edge, and corners. Very thin slabs, even if heavily reinforced, may require backfilling with hardcore, or thicker slabs may have to be used, if the ground is liable to swell and contract. The length of slab between expansion joints should be at least 15 ft. and may be up to 30 ft., or 100 ft. if dummy or contraction

joints are introduced. Since runways are not subjected to the continual hammering and vibration caused by traffic on roads, a simple butt joint may be suitable for the transverse joints. Sketches are given of longitudinal joints suitable for various types of soil. Dowels at transverse joints should be 12 in. apart. Standard steel-pipe $\frac{3}{4}$ in. in diameter has proved much more effective in the U.S.A. than round steel bars. Tie-bars at longitudinal joints should be $\frac{1}{2}$ in. in diameter, and 2 ft. 6 in. apart.

Construction. Final specifications will depend on the materials available. Cement should be specified by weight, as 580 lb./cu. yd. of finished concrete for a wearing course, 510 lb./cu. yd. for base course and 540 lb./cu. yd. where there is only one course. Test cubes should be taken at intervals, and when broken after 28 days should show a strength of 6,000 lb. for wearing course, 4,000 for base course and 5,000 for a single course. Pumped concrete may prove useful for buildings and elsewhere on aerodromes, but construction will be too slow for runways. Consolidation and finishing may be done by hand tampers, mechanical tampers or vibration. The success of the last depends on the design of the mix, which must be stiff and well-graded and contain less sand than for hand-tamped concrete. If when the vibrator has covered 2 ft. in 20 sec. the mortar does not appear on the surface, the mix is probably too dry or has too little sand. If the mix is too wet tamping will be inadequate and there may be segregation. The value is stressed of using hot water for mixing in cold weather. By this means speed is kept up, concreting is possible on days when it would not otherwise be so, and the concrete hardens off more rapidly. Contracts for which construction may take place between November and April should allow for this.

72. Speed in Concrete Airport Paving : A. A. ANDERSON: *Aero Digest*, 1941, 39 (2), 88, 90. Speed in placing concrete need not entail a sacrifice of quality since it depends on availability and organization of materials, machinery, and manpower. At Phoenix Military Airport about 11,500 sq. yd. for runway shoulders had to be laid daily, and this was done by employing 5 pugmill mixers and working three 8-hr. shifts. A lean mix was used, compacted by rolling with an ordinary road roller. The aggregate was pit-run or bank-run gravel screened into two sizes and recombined. About 3 sacks of cement (1 sack = 94 lb.) per cu. yd. of total material were used. Alternate lanes 12.5 ft. wide were laid, and when these had hardened the intermediate lanes were laid. At Ellington Field, Houston, Tex., 20,000 sq. yd. were laid daily using 4 single-drum mixers with four full concreting crews during each of two 8- to 10-hr. shifts. The concrete was given a preliminary finish by two-screed mechanical finishers, hand-floated longitudinally and finished with a light belt.

73. Paving Methods at an Eastern Airbase : ANON.: *Engng News-Rec.*, 1942, 128 (1), 12-3. Aprons and runways 150 ft. wide at an Army

airbase in the eastern U.S.A. involved nearly 500,000 sq. yd. of concrete surfacing. The apron surfacing was reinforced; the runway surfacing was not. Design and construction methods, which are described, were similar to those used in large-scale road construction, except that the apron paving, and to a lesser extent the runways, had many short runs that required extensive moving of the heavy equipment. To move the finishing machines without delay, the contractors devised a skid arrangement of the stone-boat type built of two long channels with steel paving forms set at right angles to the channels and all job-welded into a rigid frame. The forms used were salvaged from bent material and were spaced at the wheel-gauge of the finishing machine, which ran on to them under its own power. The whole outfit was dragged by a tractor to its next point of use. The cement for the runways contained 0.028 per cent. of Vinsol resin to check salt-scaling of the surfacing (see *Road Abstr.*, 1942, 9, No. 264).

74. Agricultural and Engineering Technique in the Construction of Airfields and Airports : W. PAESCHKE: *Flughafen*, 1941, 9 (9), 9-11; (10), 12-6. This paper is mainly concerned with the design, drainage and maintenance of turfed airfields. The practicability of a turfed field depends on climatic conditions, heaviness and nature of traffic and other factors, but given a suitable climate and soil it can be maintained in good condition. The greatest dangers are too much water, which in a heavy soil will give rise to rutting, and too little water, which will make a light soil dusty. Hence climate and soil must be carefully studied before choosing grass-seed. There should be 60 per cent. of under grass, 30 per cent. of over grass and 10 per cent. of clover. Maintenance consists in (1) cutting or grazing under sheep, (2) fertilizing, (3) patching, and (4) snow-disposal. (1) The method will depend on the auxiliary use if any, to which the airfield is put, i.e. cutting for cattle-food, cutting for hay or grazing for sheep. Of these the last is the most important. Precautions are suggested when an airfield is used in any of these ways. (2) The chief rule for fertilizing is "little and often." Types and combinations of fertilizers and manure are mentioned. (See also following Abstract.) (3) Special attention may be given in the spring to worn spots, but where more than half the grass has disappeared new turf must be laid. In a heavy loam or clay a layer of gravel may be incorporated before patching. (4) Snow may be cleared by ordinary snow-ploughs, a lengthy and expensive method, or rotary snow-ploughs. Some types of snow can be consolidated by means of corrugated rollers to produce a surface serviceable for aircraft. In America depths of more than 1.2 m. (3.9 ft.) have been successfully treated with rubber rollers to which the snow does not stick. Outworn aircraft engines fitted with airscrews may be run in order to disperse light snow by the air-current. The drainage of airfields comprises surface and sub-drainage and water control by means of sluices. It may be necessary in dry seasons to supply water. In a subtropical climate such as the south

of France, a surface network 7·9 to 9·8 in. deep is sufficient, consisting of 2-in. concrete pipes 32·8 ft. apart, leading to drains of centrifugally cast concrete pipe 9·8 to 11·8 in. in diameter. The trenches are filled with porous material of 2 to 2·7 in. size. In Germany collector pipes should be 27 to 31 in. deep and drains 31 to 39 in. deep. The former should be 26·2 ft. to 32·8 ft. apart, according to the type of soil. Trenches should be filled with gravel, broken stone, slag, peat, etc., and the top 9·8 to 11·8 in. with a mixture of sand and humus. Heavy soils may have a cross-drainage system, and particular spots may have trenches filled with porous material. A number of bibliographic references are given.

75. **The Fertilizing of Grassland on Airports** : G. KAVEN : *Flughafen*, 1941, 9 (10), 17-8. Grassland on airports cannot be kept in good condition, nor can it provide food for animals, without the systematic application of fertilizers and manures. The most important substance to be supplied in this way is nitrogen, which may be given in the form of various artificial fertilizers such as sulphate of ammonia, lime-nitrogen, etc. A certain amount of organic material is also necessary, and the individual soil and climate must be considered. A table shows the purpose of the principal chemical fertilizers, with the seasons and quantities in which they should be applied.
